

# CRS Report for Congress

## Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program

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Prepared for Members and  
Committees of Congress

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# Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program

## Summary

Current U.S. nuclear warheads were deployed during the Cold War. The National Nuclear Security Administration (NNSA) maintains them with a Life Extension Program (LEP). NNSA questions if LEP can maintain them indefinitely on grounds that an accretion of minor changes introduced in replacement components will inevitably reduce confidence in warhead safety and reliability over the long term.

Congress mandated the Reliable Replacement Warhead (RRW) program in 2004 “to improve the reliability, longevity, and certifiability of existing weapons and their components.” Since then, Congress has specified more goals for the program, such as increasing safety, reducing the need for nuclear testing, designing for ease of manufacture, and reducing cost. RRW has become the principal program for designing new warheads to replace current ones.

The program’s first step was a design competition. The winning design was selected in March 2007. If the program continues, NNSA would advance the design of the first RRW, assess its technical feasibility, and estimate cost and schedule in FY2008; start engineering development by FY2010; and produce the first deployable RRW between FY2012 and FY2016. Congressional actions on the FY2008 national defense authorization bills (H.R. 1585, S. 1547) and energy and water appropriations bills (H.R. 2641, S. 1751) have called this schedule into question. For details, see CRS Report RL32929, *The Reliable Replacement Warhead Program: Background and Current Developments*, which provides background and tracks legislation and developments. Each year, Congress would decide whether to fund the program as requested, modify it, or cancel it, and whether to continue or halt LEP.

RRW’s supporters argue that the competing designs meet all goals set by Congress. For example, they claim that certain design features will provide high confidence, without nuclear testing, that RRWs will work. Some critics respond that LEP should work indefinitely and question if RRW will succeed. They hold that LEP meets almost all goals set by Congress, and point to other LEP advantages. Others maintain that the scientific tools used to create RRW designs have not been directly validated by nuclear tests, and that the accretion of changes resulting from LEP makes the link of current warheads to the original tested designs increasingly tenuous. In this view, nuclear testing offers the only way to maintain confidence in the stockpile. RRW raises other issues for Congress: Is RRW likely to cost more or less than LEP? How much safety, and how much protection against unauthorized use, are enough? Should the nuclear weapons complex be reconfigured to support RRW? And what information does Congress need to choose among the alternatives?

This report is intended for Members and staff interested in U.S. nuclear weapon programs. It will be updated occasionally.

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# Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program

## Introduction

Nuclear weapons will continue to play a key role in U.S. security policy for many decades. Yet the Department of Defense (DOD) and the National Nuclear Security Administration (NNSA), the Department of Energy (DOE) agency in charge of the nuclear weapons program, have raised concerns that maintaining current weapons, which date from the Cold War, will become increasingly difficult.

At issue for Congress is how best to maintain the nuclear stockpile so that it will retain, for many decades, capabilities that political and military leaders deem necessary. There are three main options: (1) extend the service lives of current warheads without nuclear testing; (2) develop, build, and deploy a new generation of warheads without testing to replace the current stockpile; or (3) resume nuclear testing, which the United States suspended in 1992, as a tool to help maintain existing warheads or develop new ones.

This report focuses on the first two options. It compares how they respond to congressional goals, presenting pros, cons, uncertainties, costs, and potential risks and benefits, then discusses issues for Congress. Regarding the third option, the United States has not conducted a nuclear test since 1992, yet has assessed for the past 11 years that current warheads are safe and reliable. The Administration and many in Congress prefer not to resume nuclear testing, so this report does not consider it as a separate option, but discusses it at various points because testing would provide additional data to help maintain or develop nuclear weapons. This report does not consider a fourth option, abolition of U.S. nuclear weapons, as it has garnered no support in Congress or the Administration.<sup>1</sup>

## Background

Almost all warheads in the current stockpile were built in the 1970s and 1980s. They require ongoing surveillance and maintenance because their components deteriorate. In the wake of the nuclear test moratorium that the United States has observed since 1992, Congress instituted the Stockpile Stewardship Program (SSP) in 1993 “to ensure the preservation of the core intellectual and technical

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<sup>1</sup> See, however, George Shultz, William Perry, Henry Kissinger, and Sam Nunn, “A World Free of Nuclear Weapons,” *Wall Street Journal*, January 4, 2007, p. 15; and Mikhail Gorbachev, “The Nuclear Threat,” *Wall Street Journal*, January 31, 2007, p. 13.

competencies of the United States in nuclear weapons.”<sup>2</sup> SSP has provided the technical basis for advancing the relevant science in an effort to maintain confidence in U.S. warheads without nuclear testing. NNSA requests \$6,511.3 million for SSP, under the heading “Weapons Activities,” for FY2008.<sup>3</sup> Part of SSP is the Life Extension Program (LEP), which seeks to maintain warheads by replacing certain components, as needed, with newly-fabricated ones that stay as close as possible to the originals; other components may be modified. For details on congressional action on FY2008 authorization and appropriations bills, see CRS Report RL32929, *The Reliable Replacement Warhead Program: Background and Current Developments*, by Jonathan Medalia, which provides background and tracks legislation and developments.

NNSA is concerned that it will become increasingly difficult to maintain high confidence in current warheads for the long term with LEP. Reflecting this concern, Congress initiated the Reliable Replacement Warhead (RRW) program in the FY2005 Consolidated Appropriations Act (P.L. 108-447) “to improve the reliability, longevity, and certifiability of existing weapons and their components.”

NNSA executes the RRW program in cooperation with DOD, the “customer” for nuclear weapons, through the Nuclear Weapons Council, a joint DOD-NNSA organization that oversees and coordinates nuclear weapon activities. When DOD needs a new warhead, or when NNSA must modify a warhead, the council establishes a warhead Project Officers Group (POG) to develop draft “military characteristics” that the warhead must meet, such as explosive yield. The RRW POG has representatives from key stakeholders: Office of the Secretary of Defense, NNSA, U.S. Strategic Command, Navy, Air Force, and design teams. It spelled out military characteristics for RRW and established RRW program priorities that the council has vetted. Safety is the first priority; security/use control is the second. Others — certifiability, cost, longevity, manufacturability, reliability, survivability in nuclear environments, and yield — are not rank-ordered.<sup>4</sup>

NNSA must also meet policy goals in designing or maintaining warheads. Congress, mainly through FY2006 legislation and committee reports, spelled out at least 20 goals for RRW in the following categories: reduce the need for nuclear testing; improve safety and use control; design for manufacturing and maintenance; fulfill current mission requirements but not new ones; facilitate upgrading the nuclear weapons complex (the “Complex”; see **Appendix A**); and reduce the cost of the stockpile and Complex. RRW designs seek to meet all these goals.

The Nuclear Weapons Council started a competition between a New Mexico (NM) design team composed of Los Alamos National Laboratory (LANL) (NM) and

<sup>2</sup> P.L. 103-160, FY1994 National Defense Authorization Act, Section 3138(a).

<sup>3</sup> U.S. Department of Energy. Office of Chief Financial Officer. *FY 2008 Congressional Budget Request*. Vol. 1, National Nuclear Security Administration. DOE/CF-014, February 2007, p. 3, at [[http://www.mbe.doe.gov/budget/08budget/Content/Volumes/Vol\\_1\\_NNSA.pdf](http://www.mbe.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf)].

<sup>4</sup> Information provided by Dr. Barry Hannah, SES, Chairman of the RRW POG and Branch Head, Reentry Systems, Strategic Systems Program, U.S. Navy, October 31, 2006.

Sandia National Laboratories' NM site, and a California (CA) team of Lawrence Livermore National Laboratory (LLNL) (CA) and Sandia's CA site. Both teams created preliminary warhead designs between October 2005 and March 2006, then did further detailed design work. According to a December 2006, statement, the Nuclear Weapons Council determined that RRW is a feasible strategy for sustaining U.S. nuclear weapons without testing.<sup>5</sup> It selected the California design in March 2007 as the first RRW, or RRW-1.<sup>6</sup>

Nuclear weapons development proceeds in "phases" that have been defined for many years, from Phase 1 (concept assessment) to Phase 7 (retirement). For FY2008, NNSA requests funds mainly for Phase 2A (design definition and cost study), with some funds for Phase 3 (development engineering). As of July 2007, the Navy-led RRW POG is conducting a Phase 2A, design definition and cost study. The Lawrence Livermore, Los Alamos, and Sandia National Laboratories are working within the POG study to refine the design, review tradeoff options, plan the potential development program, and estimate costs of the California design.<sup>7</sup>

The choice between LEP, RRW, or some combination is important because it will set the course for U.S. nuclear weapons for decades to come, and each year it is up to Congress to decide whether to fund these programs as requested, or modify or cancel them. A crucial decision is whether to move RRW to Phase 3 from the current Phase 2A. While the Nuclear Weapons Council had envisioned completion of Phase 2A by the end of December 2007, it appears unlikely that Congress will make a decision on Phase 3 in the FY2008 budget cycle, as the defense authorization bills reported by the House and Senate Armed Services Committees (H.R. 1585 and S. 1547, respectively) and the energy and water appropriations bill reported by the Senate Appropriations Committee (S. 1751) recommended holding RRW in Phase 2A in FY2008. Further, the energy and water appropriations bill as passed by the House (H.R. 2641) provided no funds for RRW.

There are many RRW issues to resolve. Cost is important to any decision to proceed with RRW, yet long-term cost projections are notoriously unreliable. There are technical uncertainties, such as whether the winning RRW design can be turned into a functioning warhead. The future Complex has yet to be determined, along with how it might differ depending on whether the United States pursues LEP or RRW and how it would handle a transition to an all-RRW stockpile. Stockpile numbers decades out are unknowable, yet a Complex would spend money unnecessarily if sized too large and could not support requirements if sized too small. A commenter noted that while claims are made that RRW is cheaper, safer, more reliable, etc., than LEP, or vice versa, in many cases "no numbers exist to substantiate the claim. The proponents of either approach, in many cases, while

<sup>5</sup> U.S. Department of Energy. National Nuclear Security Administration. "Nuclear Weapons Officials Agree to Pursue RRW Strategy," press release, December 1, 2006.

<sup>6</sup> U.S. Department of Energy. National Nuclear Security Administration. "Design Selected for Reliable Replacement Warhead." Press release, March 2, 2007.

<sup>7</sup> Information provided by Lawrence Livermore National Laboratory, July 13, 2007.

implying a measurable effect are really saying ‘believe me.’”<sup>8</sup> Beyond RRW issues are broader issues of strategic policy.

Accordingly, many in Congress want NNSA to use FY2008 to perform further Phase 2A work, and others to study broader issues. For example, the report on H.R. 2641 stated: “it is premature to continue design activities for a new nuclear warhead until a revised U.S. nuclear weapons strategy is developed that describes the long term nuclear stockpile requirements and demonstrates how a new nuclear warhead is necessary to address specific U.S. national security requirements and nuclear nonproliferation commitments.”<sup>9</sup> Other committees recommended related studies, such as on linking U.S. strategic and nonproliferation goals, nuclear weapon missions, nuclear weapon numbers and types, and the nuclear weapons complex; see CRS Report RL32929 for details.

The FY2007 National Defense Authorization Act (P.L. 109-364, Section 3111) sets as an objective having the RRW first production unit (FPU, the first complete warhead from a production line certified for deployment) in 2012, and the FPU is scheduled for September 2012. NNSA stated in April 2007 that a 2012 FPU remains its target date. There is some uncertainty about NNSA’s ability to meet that date. Barry Hannah, Chairman of the RRW POG, stated, “I believe that an FPU of FY2012 for the first RRW is extremely optimistic.”<sup>10</sup> A Nuclear Weapons Council memorandum of March 2007 states, “Given the level of maturity of the [RRW] design effort to date, our planning target for the First Production Unit, is 2014 plus or minus two years.”<sup>11</sup>

## **Relationship among Goals**

Many goals Congress set for RRW are interrelated. A more efficient Complex and increased confidence in long-term reliability might let DOD retain fewer nondeployed warheads as a hedge against reliability problems or adverse geopolitical changes. Wider performance margins would give DOD more confidence in NNSA’s ability to certify warheads without testing. The effort to design and produce an RRW that offers greater resistance to unauthorized use, that is easier to manufacture, and that increases performance margins should help maintain design and production expertise. Using more environmentally benign materials should increase safety and ease of manufacture and facilitate a smaller and more modern Complex.

Many goals seek to reduce cost over the long term. Reducing the use of hazardous materials requires less equipment to shield workers and protect the

<sup>8</sup> Personal communication, September 7, 2006.

<sup>9</sup> U.S. Congress. House. Committee on Appropriations. *Energy and Water Development Appropriations Bill, 2008*, H.Rept. 110-185, to accompany H.R. 2641, 110<sup>th</sup> Congress, 1<sup>st</sup> Session, 2007, p. 100.

<sup>10</sup> Information provided by Dr. Barry Hannah, SES, Branch Head, Reentry Systems, Strategic Systems Program, U.S. Navy, telephone conversation with the author, October 23, 2006.

<sup>11</sup> Ibid., attachment by RADM S.E. Johnson, U.S. Navy, and T. D’Agostino, NNSA.

environment, permits some work to be done outside of high-cost buildings, and reduces waste streams. Moving some work outside of high-cost buildings to make space available inside them may permit more production lines to be installed in such buildings, increasing their productivity. Designing warheads for ease of manufacture, assembly, and maintenance is likely to save money by requiring fewer process steps, reducing the equipment and workers to support those steps, and permitting more rapid production. Less rigid tolerances and wider design margins reduce costs by reducing the number of rejected components, increasing throughput, and reducing waste streams. Making a warhead more resistant to terrorist attack could slow the growth of physical security costs.

While Congress has specified many goals, it did not set a clear goal on an issue that it has considered for other nuclear weapons: whether RRW is to be a “new warhead.” Congressional language on this point may appear ambiguous. For example, the program is “to improve the reliability, longevity, and certifiability of existing weapons and their components”;<sup>12</sup> a goal is “to develop replacement components for nuclear warheads”;<sup>13</sup> another goal is “[t]o ensure that the nuclear weapons infrastructure can respond to unforeseen problems, to include the ability to produce replacement warheads”;<sup>14</sup> “any new weapon design must stay within the design parameters validated by past nuclear tests”;<sup>15</sup> and a committee’s “qualified endorsement of the RRW initiative is based on the assumption that a replacement weapon will be designed only as a re-engineered and remanufactured warhead for an existing weapon system in the stockpile.”<sup>16</sup>

Part of the ambiguity is semantic. “Warhead” refers clearly to a nuclear explosive device, but “weapon” may mean a warhead or its delivery system. If “weapon” refers to delivery system, then the warhead may be viewed as a “component” of the delivery system. If “weapon” refers to “warhead,” then a component would be a part of a warhead. The term “new” is also ambiguous. While neither competing RRW design is exactly like any warhead currently deployed, each design contains key components that are similar to those of current warheads.

<sup>12</sup> U.S. Congress. Committee of Conference. *Making Appropriations for Foreign Operations, Export Financing, and Related Programs for the Fiscal Year Ending September 30, 2005, and for Other Purposes*, conference report to accompany H.R. 4818, 108<sup>th</sup> Cong., 2<sup>nd</sup> sess., H.Rept. 108-792, 2004, p. 951.

<sup>13</sup> U.S. Congress. Senate. Committee on Armed Services. *National Defense Authorization Act for Fiscal Year 2006*. S.Rept. 109-69 to accompany S. 1042, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 482.

<sup>14</sup> P.L. 109-163, FY2006 National Defense Authorization Act, Section 3111.

<sup>15</sup> U.S. Congress. Committee of Conference. *Making Appropriations for Energy and Water Development for the Fiscal Year Ending September 30, 2006, and for Other Purposes*. H.Rept. 109-275 to accompany H.R. 2419, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 159.

<sup>16</sup> U.S. Congress. House. Committee on Appropriations. *Energy and Water Development Appropriations Bill, 2006*. H.Rept. 109-86 to accompany H.R. 2419, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 130.

Whatever the case, NNSA could not meet the goals for RRW by modifying current warheads. A dominant design consideration of these Cold War warheads was maximizing yield to weight — having the most explosive energy possible within a tight weight budget so that more warheads could be placed on a missile. To pare down weight, some warheads used a nuclear explosive package (NEP; see **Appendix A**) designed with parameters close to the point at which the warhead would fail to meet its design requirements. NNSA expresses concern about the impact of even minor changes to NEP components that the Life Extension Program might introduce. These tight designs could not undergo drastic modifications needed to accommodate such goals as increased safety and use control, lower cost, and reduced use of hazardous materials and still provide confidence that they would work as intended.

## Terminology and Pending Studies

This report refers to “supporters” and “critics” of RRW. While this division may oversimplify matters, it permits the report to highlight key points of contention while avoiding a tedious discussion of minor differences. In general, supporters of LEP are critics of RRW, and vice versa, but finer divisions of opinion exist. Raymond Jeanloz, Professor of Earth and Planetary Science at the University of California at Berkeley and a long-time adviser to the U.S. government on technical aspects of national and international security, said, “I still don’t think of myself as being in the ‘critic’ [of RRW] category because I find that many of the objectives motivating [RRW] are reasonable, and it’s more in the implementation (and interpretation of what is needed) where I find myself concerned.”<sup>17</sup> Some RRW supporters question aspects of RRW designs. And supporters of RRW are not necessarily critics of LEP. As Los Alamos states,

We have been asked to study the feasibility of RRW-design enabled by relaxing yield/weight. We have found compelling designs that provide added margin, surety, and manufacturability in our studies. Just because this exercise has been successful does not imply that we’re opponents of LEP-strategies. At the end of the day, we are service providers and advisors. We will pursue the course of action decided by the Administration, Congress, and the DoD. If they wish to pursue LEPs, then we’re fully committed to that path and will provide our best advice and service.<sup>18</sup>

This report offers two terminological notes. First, as the RRW program has progressed and congressional goals for it have become clearer, the term “Reliable Replacement Warhead” no longer seems appropriate. It implies that current warheads are not reliable, which Ambassador Linton Brooks, the head of NNSA, has emphatically denied.<sup>19</sup> It implies that reliability is the program’s goal, yet Congress

<sup>17</sup> Personal correspondence, September 7, 2006.

<sup>18</sup> Information provided by Los Alamos National Laboratory, September 20, 2006.

<sup>19</sup> According to Brooks, “*Stockpile Stewardship is working*; the stockpile remains safe and reliable.” “Statement of Ambassador Linton F. Brooks, Under Secretary for Nuclear Security and Administrator, National Nuclear Security Administration, U.S. Department of Energy, Before the Senate Armed Services Committee, Subcommittee on Strategic Forces,” (continued...)

has set forth dozens of goals. It deemphasizes “replacement,” yet a key goal of RRW is to replace existing warheads in such a way as to be used on existing aeroshells<sup>20</sup> and missiles. Second, this report distinguishes between “Competing Candidate RRW Designs,” or CCRDs, which currently exist; the RRW program; and RRWs, actual warheads that may be built in the future.

Several external reviews of the program are forthcoming. The House Appropriations Committee directed NNSA to have the JASONs, a group of scientists who advise the government on defense matters, conduct an independent peer review

to evaluate the competing RRW designs. The JASONs should evaluate the RRW design recommended by the POG [the RRW Project Officers Group] against the requirements defined by congressional legislative actions to date and the elements defined in the Department of Defense’s military characteristics for a reliable replacement warhead requirements document. The JASON review should also include an analysis on the feasibility of the fundamental premise of the RRW initiative that a new nuclear warhead can be designed and produced and certified for use and deployed as an operationally-deployed nuclear weapon without undergoing an underground nuclear explosion test.<sup>21</sup>

The report was due March 31, 2007.<sup>22</sup> The schedule for this report as decided by the JASONs, NNSA, and the House Appropriations Committee calls for a preliminary report to be submitted to NNSA by March 1, 2007, an executive summary of the final report by August 1, 2007, and the final report by October 1, 2007.<sup>23</sup> The preliminary report, which is classified, was submitted in late January.<sup>24</sup> The Nuclear Weapons Complex Assessment Committee of the American Association for the Advancement of Science (AAAS) studied whether RRW is the best path for addressing certain potential risks of SSP and LEP and for developing a responsive infrastructure in a report released April 24, 2007.<sup>25</sup> A third report, mandated by the FY2006 National

<sup>19</sup> (...continued)

March 7, 2006, p. 1 (original emphasis); at [<http://armed-services.senate.gov/statemnt/2006/March/Brooks%2003-07-06.pdf>].

<sup>20</sup> An aeroshell, generally called a reentry vehicle by the Air Force and a reentry body by the Navy, is the cone-shaped shell that carries an individual warhead on a ballistic missile. It protects the warhead against burnup as it reenters the atmosphere at high speed and minimizes degradation of accuracy.

<sup>21</sup> U.S. Congress. House. Committee on Appropriations. *Energy and Water Development Appropriations Bill, 2007*, H.Rept. 109-474 to accompany H.R. 5427, 109<sup>th</sup> Cong., 2<sup>nd</sup> sess., 2006, p. 110.

<sup>22</sup> Ibid.

<sup>23</sup> Information provided by Roy Schwitters, S.W. Richardson Foundation Regental Professor of Physics, University of Texas at Austin, and Chair of the JASON Steering Committee, email, January 29, 2007.

<sup>24</sup> Information provided by Professor Roy Schwitters, email, March 27, 2007.

<sup>25</sup> American Association for the Advancement of Science. Center for Science, Technology and Security Policy. Nuclear Weapons Complex Assessment Committee. C. Bruce Tarter, (continued...)

Defense Authorization Act, P.L. 109-163, Section 3111, is to discuss RRW's "feasibility and implementation." It was due March 1, 2007. It will "discuss the relationship of the Reliable Replacement Warhead program within the Stockpile Stewardship Program and its impact on the current Stockpile Life Extension Programs." As of July 13, the report was in interagency coordination and had not been transmitted to Congress.

## Meeting Congressional Goals

This report now discusses how the competing designs and LEP seek to meet congressional goals and presents the debate by supporters of LEP, RRW, and others. Some of these goals are taken directly from congressional language, while others are derived from it. To help the reader link goals to congressional language, each goal is followed by one or more numbers in brackets. These numbers refer to excerpts from legislation (excerpt 2) or committee reports (other excerpts) in **Appendix B**.

### Warhead Characteristics: Reduced Need for Nuclear Testing

In order to maximize yield to weight, warheads were designed close to points at which they would fail, but nuclear testing helped provide sufficient confidence that they could be placed in the stockpile. The United States has been able to maintain its weapons despite the moratorium on nuclear testing largely because SSP has developed or improved upon many means — such as nonnuclear experiments, large and small experimental facilities, computer simulations, and new analyses of data from past nuclear tests — to better understand warhead performance in order to anticipate, identify, and fix warhead problems. As a result, the Secretaries of Defense and Energy have made 11 annual assessments that each warhead type in the stockpile remains safe and reliable, and that testing is not required.

Yet NNSA and its labs have expressed concerns that, over the long term, minor changes to current warheads through repeated LEPs and maintenance will decrease confidence in the warheads, possibly requiring a return to nuclear testing. Critics counter that careful attention to minimizing changes, and advances in understanding of the relevant science, should keep existing warheads reliable for many years.

Because of its desire to avoid testing, Congress has stated that a goal for RRW is to minimize the need to return to testing. NNSA claims that the RRW program will meet this goal because of steps, discussed below, to increase confidence. LEP's proponents respond that the lack of a nuclear test "pedigree" reduces confidence in RRWs. Others maintain that certification using SSP has been a political assessment rather than a technical one. Since SSP emerged *after* the moratorium on testing began, this position holds that its tools were never validated with nuclear tests done for that purpose, so they could lead to false conclusions. Accordingly, in this view,

<sup>25</sup> (...continued)

Chair. "The United States Nuclear Weapons Program: The Role of the Reliable Replacement Warhead." April 2007, 34 p. Available at [<http://cstsp.aaas.org/files/AAAS%20RRW%20Report.pdf>].

NNSA will not know for sure if SSP, and thus RRW or LEP, work until it conducts nuclear tests.<sup>26</sup> As former LANL Director Siegfried Hecker stated in 1997,

Of course, if nuclear testing were allowed, we would gain greater confidence in the new tools. We could validate these tools more readily, as well as validate some of the new remanufacturing techniques. One to two tests per year would serve such a function quite well. Yields of 10 kt would be sufficient in most cases. Yields of 1 kt would be of substantial help.<sup>27</sup>

**1. Maintain high warhead reliability.** [1, 2, 4, 6, 7]<sup>28</sup> A Sandia report defines reliability for a nuclear warhead as “[t]he probability of achieving the specified yield, at the target, across the Stockpile-To-Target Sequence of environments, throughout the weapon’s lifetime, assuming proper inputs.”<sup>29</sup> In this definition, the specified yield is generally understood to mean within ten percent; the Stockpile-To-Target Sequence of environments is the range of conditions the warhead is expected to experience in its service life in storage, transit, or use, such as temperature extremes, radiation from any nuclear-armed missile defense interceptors, and acceleration; lifetime is the “original lifetime objective as specified at the time of design”; and proper inputs are arming, fuzing, and firing signals.

The designers of the first RRW, RRW-1, have sought to obtain high reliability by maximizing margins (building in more performance than is needed; see next section). The design teams argue that they could do so because the designs were unconstrained by technologies and design choices made decades ago. With wide margins, they claim, material deterioration or design or manufacturing defects are less likely to degrade warhead performance below the minimum required. Further, diagnostic systems that could be incorporated in the designs would help detect deterioration at an early stage. In contrast, RRW advocates project increasing difficulty in maintaining the reliability of existing warheads. Sandia stated, “As systems age and [warhead] lives are extended, changes due to aging or repair creep into the system that make it more difficult to predict performance, and repair itself becomes more challenging as we move further away from the design era.”<sup>30</sup>

LEP’s supporters argue that current warheads are reliable, as evidenced by 11 stockpile assessments. While problems emerge, solutions do as well, and LEP supporters argue that SSP has been keeping at least even in this race. RRW supporters agree with this latter statement; an NNSA official stated, “Each year, we are gaining a more complete understanding of the complex physical processes

<sup>26</sup> Information provided by Kathleen Bailey, former Assistant Director for Nuclear and Weapons Control, U.S. Arms Control and Disarmament Agency, November 28, 2006.

<sup>27</sup> S.S. Hecker, “Answers to Senator Kyl’s questions,” in Senate Committee on Governmental Affairs, *Safety and Reliability of the U.S. Nuclear Deterrent*, p. 83.

<sup>28</sup> As noted, these numbers refer to excerpts from congressional language in Appendix B.

<sup>29</sup> R.L. Bierbaum et al., “DOE Nuclear Weapon Reliability Definition: History, Description, and Implementation,” Sandia National Laboratories, report SAND99-8240, April 1999, p. 8. Available at [<http://www.wsflweb.org/docs/usg/reli99.pdf#search=%22doe%20nuclear%20weapon%20reliability%20definition%22>].

<sup>30</sup> Information provided by Sandia National Laboratories (NM), August 3, 2006.

underlying the performance of our aging nuclear stockpile.”<sup>31</sup> LEP supporters challenge the view that reliability of current warheads must decline. Richard Garwin, IBM Fellow emeritus, said, “with the passage of time and the improvement in computing tools, I believe that confidence in the reliability of the existing legacy weapons will increase rather than diminish, just as has been the case with the nuclear weapon pits.”<sup>32</sup> They question if RRW will improve reliability. Steven Fetter, Dean, School of Public Policy, University of Maryland, said, “Like most other warheads, RRW will have, or could be expected to have, birth defects or reliability problems that would be discovered and corrected soon after the warhead was deployed. No one can say whether the unreliabilities introduced by these birth defects would be greater or smaller than the unreliabilities that would crop up in the existing warheads due to their age.”<sup>33</sup>

Some doubt that either LEP or RRW can be assessed as reliable. They contend that stewardship tools should not be relied on, and that RRWs cannot be assessed as reliable without testing because of questions about how new warheads will function. They also contend that LEPs cannot be assessed as reliable without testing because LEPs will inevitably introduce small changes into warheads, and their cumulative effect will undermine confidence in reliability.<sup>34</sup>

**2. Increase performance margins.** [3, 7] Margins, uncertainty, and confidence are important for understanding risks of implementing RRW or LEP without nuclear testing. For a given characteristic, a minimum value is required for a warhead to operate as intended. Margin is the amount by which the design parameter exceeds that minimum — the excess performance built into the design. A warhead’s design provides a higher value than the minimum for each characteristic to ensure margin and avoid failure. Uncertainty results from imprecise knowledge of design parameters and of the minimum value required to ensure performance. The labs use computer models, experimental data, etc., to bound these uncertainties. Confidence is the ratio of margin to uncertainty: if margin is high and uncertainties low, confidence is high; if both are high, confidence is low. Having margins greater than uncertainties provides confidence against potential failure modes.

The close relationship of margins, uncertainties, and confidence is formalized in Quantification of Margins and Uncertainties, or QMU, an analytic framework that LANL and LLNL have developed. They are implementing it to assess, in the absence of testing, confidence in weapon performance. Since its inception, the nuclear

<sup>31</sup> “Statement of Thomas P. D’Agostino, Deputy Administrator for Defense Programs, National Nuclear Security Administration, Before the House Armed Services Committee, Subcommittee on Strategic Forces,” April 5, 2006, p. 1.

<sup>32</sup> U.S. Congress. House. Committee on Appropriations. Subcommittee on Energy and Water Development. Hearing on nuclear weapon activities. 109th Congress, 1st Session, March 29, 2007.

<sup>33</sup> Arms Control Association, “The Future of U.S. Nuclear Weapons: The Weapons Complex and the Reliable Replacement Warhead,” press briefing, Washington, DC, April 19, 2007.

<sup>34</sup> Information provided by Robert Barker, former Assistant to the Secretary of Defense for Atomic Energy, November 29, 2006.

weapons program has used the core principle of QMU, building margins into warhead designs, to assess performance risk, such as identifying situations where small changes could cause performance to degrade sharply.

Current missile warheads maximize explosive yield while minimizing warhead weight. For example, to minimize weight, a warhead's primary stage (see **Appendix A**) has little yield above that needed to make the warhead work as intended. While this approach resulted in "thin" margins, nuclear testing helped provide confidence that warheads would work. For RRW, DOD traded off a reduction in yield per unit of weight to improve margin (as well as safety and use control). To gain confidence without testing, both teams used metrics that were derived statistically from the nuclear testing database but that can be obtained without nuclear testing, such as through calculations or hydrodynamic experiments.<sup>35</sup> Using existing nuclear test data, the labs found that if these metrics exceed certain values, there is very high confidence that the primary will work as intended. Knowing this, designers at both labs adjusted CCRDs so that primary margins greatly exceed the minimum required.

The design teams claim a key advantage for the competing designs: because the designs start fresh, designers can increase margin. The teams view added margin as the single most important goal of the designs, as it enables confidence without testing by compensating for unanticipated uncertainties. In contrast, they argue, one cannot increase margin in an LEP in the many cases requiring changes to the warhead because that would push the warhead beyond the design envelope validated by nuclear testing. As a result, they claim, one can only attempt to drive down uncertainty, but that path has proven costly and might in some cases be unsuccessful.

RRW's critics hold that SSP, the surveillance program, and LEP can maintain margins through careful remanufacture of nuclear explosive package components to minimize changes. They also state, to general agreement, that primary margin for some warheads could be increased with no change to a warhead through revised means of dealing with the boost gas.<sup>36</sup> Critics express concern that RRWs would increase uncertainty, offsetting the potential gain in margin that advocates claim for RRW. Precisely because the design is new, critics believe RRWs are likely to have "birth defects," while such defects have been wrung out of existing designs. Critics

<sup>35</sup> These experiments use powerful high-speed x-rays and other diagnostic equipment to measure the geometry and density of a pit (made with surrogate material) as it implodes, allowing experimental determination of key values independent of computer models.

<sup>36</sup> Boost gas is a mixture of tritium and deuterium gases injected into the pit to increase its explosive energy; see Appendix A. A study found, "Primary yield margins can be increased by appropriate changes specific to each stockpile system. These include changes to initial boost-gas composition, shorter boost-gas exchange intervals, or improved boost-gas storage and delivery systems. These modifications have been validated by nuclear test data for the appropriate systems, and they would not place burdens on the maintenance or deployment of the systems by the military." National Academy of Sciences, Committee on Technical Issues Related to Ratification of the Comprehensive Nuclear Test Ban Treaty, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty*, Washington, National Academy Press, 2002, p. 31. See also JASON report JSR-99-305, *Primary Performance Margins*, McLean, VA, MITRE Corporation, 1999, p. 2. The Air Force and Navy would need to weigh the advantages and disadvantages of any specific future changes of this sort.

point to a 1996 Sandia study of stockpile surveillance that showed that the greatest number of problems requiring corrective action occurred in the first three years after FPU, a lower but still substantial number of such findings occurred in years 4-11 after FPU, and very few occurred in years 12-23.<sup>37</sup> (There are no public data on whether that number remains low, or increases, after year 23 because the study has not been updated in unclassified form.) RRW's supporters respond that LEP can also introduce birth defects.

**3. Stay within the design parameters validated by past nuclear tests.** [2, 8] The two key issues for the functioning of a nuclear weapon are (1) does the primary boost with enough energy to give its design yield, and (2) does enough energy transfer from the explosion of the primary to drive the secondary successfully. Nuclear testing used to provide data to make judgments on these issues. In addition to improved margins, another basis for confidence in the competing designs was that while both teams explored diverse potential designs, they ultimately stayed close to past experience. In direct response to congressionally-mandated requirements, the NM team rejected certain design concepts because they fell outside design parameters validated by prior nuclear testing. Livermore states,

All RRW/CA components, or components very similar to the RRW/CA primary and secondary have been nuclear tested. For example, the primary uses a tested design with a modest and very well understood modification of the pit to provide added margin. Thus there is direct nuclear test proof that the RRW/CA design will perform properly. In addition, the RRW/CA design draws on over 100 other nuclear tests to assure confidence in various materials, components, and features in the design. In addition the RRW/CA team built on LEP and Stockpile Stewardship to develop certification tools that boosted confidence in its RRW design.<sup>38</sup>

LEP advocates hold that because existing warheads have undergone extensive testing in the course of their development, they necessarily stay within design parameters validated by such tests. Those who would resume testing reply to both positions by noting that SSP, on which RRW depends, has not been validated by nuclear testing, and that changes introduced by LEPs and by minor modifications during maintenance move existing warheads away from validated design parameters.

**4. Design warheads for ease of certification without nuclear testing.** [2, 6] A certification plan defines the scope of work required to certify a warhead design to DOD. In the past, the laboratories developed warheads through an iterative process of computation, small- to large-scale experiments, and nuclear testing. That information provided grounds for issuing a Major Assembly Release<sup>39</sup> for warheads at the end of their development. LEPs are also certified in the

<sup>37</sup> Kent Johnson et al., *Stockpile Surveillance: Past and Future*, prepared by Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories, Sandia Report SAND95-2751, UC-700, January 1996, p. 32.

<sup>38</sup> Information provided by Lawrence Livermore National Laboratory, September 19, 2006.

<sup>39</sup> A Major Assembly Release is a statement from NNSA to DOD that a warhead (or major component) will meet all military requirements with any exceptions noted.

development cycle, about three to six months before first production, using SSP tools. The RRW design teams, applying lessons learned in certifying LEPs, began the certification process and design together, forcing greater attention from the outset to potential failure modes in order to increase confidence. The CA team states that it “made basic design choices that ease certification without testing.”<sup>40</sup> LANL states:

The NM design began with an exhaustive evaluation and statistical analysis of nuclear test data that led to design choices made to improve the margin for key primary and secondary performance parameters dramatically while avoiding known failure modes. These choices insured that RRW would be firmly within our nuclear test experience and provided robust performance even in the event of unanticipated failure modes. The resulting high margin-to-uncertainty ratios allow ready certification through our QMU (quantification of margins and uncertainties) approach.<sup>41</sup>

In addition, the teams used various SSP tools, such as hydrodynamic facilities (see note 35) to provide confidence that the warheads could withstand a diverse set of accident scenarios and threats. According to LANL,

hydrodynamic testing provides confidence in certifying that, even with new surety features, the design will function as intended. LANL fired its first hydrodynamic shot in support of its design on September 6, 2006, and early data analysis indicates that these features will perform as LANL’s weapons codes had predicted.<sup>42</sup>

RRW supporters note that an LEP replaces defective or deteriorated components with new ones. Unlike RRW, NEP components in an LEP must be as close as possible to the originals, which often means using the original materials and manufacturing processes. Certification of warheads that have undergone an LEP is difficult, it is argued, because it involves certification that the current manufacturing process duplicates the original process, which can generally be done closely but not precisely. The RRW design, in contrast, starts with a new design that uses modern manufacturing processes that have been selected in part for ease of certification.

RRW is an attempt to create a warhead that can be certified without testing. Some outside experts question whether it can meet this standard as well as extending the life of current warheads through LEP. According to one, the issue for RRW

has simply to do with retaining the same, or higher, confidence in our warheads’ performance if some of their parameters are altered from the values built into our current arsenal, based on a long test pedigree, and whose performance over time has been confirmed by the LEP surveillance/simulation/analysis programs. Can we meet that challenge successfully? This is the question that has to be addressed with careful analysis and independent scrutiny. We must determine how great an interpolation - not extrapolation - can be made from current design parameters, and how many parameters altered at the same time before we may

<sup>40</sup> Information provided by Lawrence Livermore National Laboratory, September 19, 2006.

<sup>41</sup> Information provided by Los Alamos National Laboratory, October 24, 2006.

<sup>42</sup> Information provided by Los Alamos National Laboratory, September 20, 2006.

be deceiving ourselves. In the end, what will it take to convince a responsible leader in the White House, or the Pentagon, or at [the U.S. Strategic Command], to have confidence in such a new design without requiring new test data? This and this alone is the standard that RRW must meet.

Another outside expert was more critical:

The present nuclear weapon stockpile contains 8 or so nuclear weapon types. That population has enjoyed perhaps 100 successful yield tests. These weapons have benefited from a test base of perhaps 1,000 yield tests conducted during the 40 or so years when nuclear testing was allowed. Is the DoD really willing to replace tested devices with untested devices? Why are Livermore and Los Alamos designing devices that can't be yield-tested?<sup>43</sup>

Other critics argue that both RRW and LEP diverge from reality. They believe that confidence in the U.S. nuclear arsenal — by the United States, its friends, and its foes alike — is so central to U.S. security that we must conduct nuclear tests, regardless of political concerns, because only testing can maintain confidence.<sup>44</sup> Supporters of LEP and RRW respond that most nuclear tests used test devices that differed somewhat from deployed warheads, so the link between fielded warheads and nuclear tests is more complex than it might appear.

## **Warhead Characteristics: Safety and Use Control**

The design teams were asked to put as much safety and use control into their designs as practical. Both designs have new features that do not appear in any current warhead to counter various accident and attack scenarios. Lawrence Livermore National Laboratory (LLNL) and Los Alamos National Laboratory (LANL) have principal responsibility for the nuclear explosive package design, which includes inherent safety. Sandia National Laboratories has principal responsibility for the design of nonnuclear components, including those for use control and safety; integration of these components into the warhead; and mechanical and electrical interfaces between the warhead and the missile or bomber that carries it. The three laboratories share responsibility for warhead features for disablement.

**5. Increase the ability of warheads to prevent unintended nuclear detonation.** [2, 3, 4, 5, 7] While all stockpile weapons meet the safety requirements specified by DOD, nuclear detonation safety cannot be assured in an abnormal environment in which the nuclear safety design configuration is breached (the weapon is broken open), the nuclear explosive package remains operable, and energy capable of initiating a nuclear detonation is present. Warheads in the current stockpile that do not have design features to guarantee that they will survive this so-called “Trinity condition” without producing a nuclear yield must have a “Trinity exception,” meaning that DOD accepts them into the stockpile with a specific

<sup>43</sup> Correspondence with Robert Peurifoy, former Vice President of Technical Support, Sandia National Laboratories, Albuquerque, NM, September 24, 2006.

<sup>44</sup> Information provided by Kathleen Bailey, former Assistant Director for Nuclear and Weapons Control, U.S. Arms Control and Disarmament Agency, November 28, 2006.

exception for that condition. Both RRW designs have certain features so that they do not require a Trinity exception. One way the NM design meets the Trinity condition is to use optical isolation, discussed under Goal 9.

LEP advocates see current warheads as safe enough. They view as farfetched such scenarios as Trinity that are used to justify RRW on grounds of reducing the risk of accidental detonation. Analysts can always develop scenarios in which a particular new weapon makes an immense difference. But the existence of a scenario does not require spending large sums to address it. Critics note that no U.S. warhead has ever detonated accidentally. While dozens of accidents have involved nuclear weapons, especially in the 1950s and 1960s, later warhead designs incorporated lessons learned, arguably reducing risk to an extremely low level.

**6. Increase the ability of warheads to prevent unauthorized nuclear detonation.** [2, 3, 4, 5, 7] Current weapon systems have use control features designed to meet Cold War threats. These features permit authorized use of a warhead in its intended mode of operation and deny unauthorized use. An example of use control, incorporated into warheads for decades, is the permissive action link, which requires insertion of a code to make the warhead work. More generally, use control is the entire release system stretching from the President to the warhead.

The 9/11 attacks changed use control requirements dramatically. As Ambassador Linton Brooks, the Administrator of NNSA, testified in 2005:

During the Cold War, the main security threat to our nuclear forces was from spies trying to steal our secrets. Today, the threat to classified material remains, but to it has been added a post-9/11 terrorist threat that is difficult and costly to counter. We now must consider the distinct possibility of well-armed and competent terrorist suicide teams seeking to gain access to a warhead in order to detonate it in place. This has driven our site security posture from one of “containment and recovery” of stolen warheads to one of “denial of any access” to warheads. This change has dramatically increased security costs for “gates, guns, guards” at our nuclear weapons sites. If we were designing the stockpile today, we would apply new technologies and approaches to warhead-level use control as a means to reduce physical security costs.<sup>45</sup>

In response to such concerns, the design teams were directed to incorporate the maximum safety and use control practical, and both designs offer a “menu” of new features to this end. LLNL states that the CA design provides an “unprecedented level of use control” that is “beyond the best in stockpile.”<sup>46</sup> LANL calls the NM design “revolutionary” in this regard. In contrast, RRW advocates note, new use control features could in general not be backfitted into current missile warheads because their designs are so tight that they could not accommodate even minor

<sup>45</sup> “Statement of Ambassador Linton F. Brooks, Administrator, National Nuclear Security Administration, U.S. Department of Energy, Before the Senate Armed Services Committee, Subcommittee on Strategic Forces,” April 4, 2005, p. 4.

<sup>46</sup> “Key Points for RRW/CA,” briefing slide, Lawrence Livermore National Laboratory, c. June 2006. An RB (reentry body) or RV (reentry vehicle) is an aeroshell, as described in note 13.

changes. (Gravity bombs are less constrained in weight because bombers can carry much more payload than missiles.)<sup>47</sup> At the same time, the new safety and use control features add cost and manufacturing complexity, and have the potential to reduce reliability by an amount the labs anticipate would be small. Some supporters question whether all possible features warrant inclusion.

Enhanced use control is very important to the Air Force, especially because ICBM warheads are more vulnerable outside of their silos. However, such features would not lead the Air Force to reduce physical security. It would be impossible to hide an operation that removes warheads from ICBMs and transports them back to the base, so the Air Force would use a large security force as a show of force even with RRWs. Enhanced use control features, though, would create more options for security forces in dealing with an accident or an attack. Accordingly, the Air Force would consider such features even though it expects that they would reduce reliability by a small amount; at issue are the relative costs and benefits of such a tradeoff. These features can be tested to see how they respond to different events, which can provide confidence in their value. The Air Force does not expect these features to affect field operations adversely, and the overall design of the RRW may make field operations easier. At this point in the development cycle, it is too early for the Air Force to know whether to recommend dropping any safety and use control features.<sup>48</sup>

Some critics believe current warheads and external physical security measures provide high use control, and question the need for more use control. There has never been an unauthorized detonation of a U.S. warhead, and means to reduce this risk have been introduced continually. Upgrading physical security or reducing the number of weapon storage sites can improve use control. Not every threat hypothesis requires a response: LEP's supporters see the risk of terrorists penetrating a heavily-guarded military base or DOE facility and detonating a nuclear weapon to be remote. Some ask if part of the funds to improve U.S. warhead security might increase U.S. security more if spent to secure Russian warheads and nuclear materials.<sup>49</sup>

Others feel that safety and use control must be increased as much as possible, and would be willing to resume nuclear tests to do so. They point to a 1997 statement by Siegfried Hecker, then Director of Los Alamos: “with a CTBT [Comprehensive Test Ban Treaty] it will not be possible to make some of the potential safety

<sup>47</sup> Thomas D'Agostino, Acting Administrator, NNSA, said, “if we were looking at providing reliable replacement concepts into a bomb, we would look primarily to one of those pits that we already know has these [security] features. And assuming the shape is not a problem, then we would use that particular pit in that system because it would have, again, offset further expense. A warhead on top of a ballistic missile is a little bit different animal because of the constraints associated with the size. And therefore, we had to kind of start from the ground up on that particular system.” (The latter reference is to the first RRW.) U.S. Congress. House. Committee on Armed Services. Subcommittee on Strategic Forces. Hearing on the FY2008 budget request for DOE atomic energy programs, March 20, 2007.

<sup>48</sup> Information provided by a senior Air Force official, interview with the author, September 26, 2006.

<sup>49</sup> Personal communication, Rob Nelson, Senior Scientist, Union of Concerned Scientists, November 22, 2006.

improvements for greater intrinsic warhead safety that we considered during the 1990 time frame.”<sup>50</sup> C. Paul Robinson, then Director of Sandia, stated in 1999:

As technology advances, opportunities will arise for improving the safety design of nonnuclear systems of nuclear weapons, and we will, of course, pursue those opportunities. While improvements to safety and security systems for nuclear weapons can be developed and implemented without nuclear explosive testing, several attractive technical concepts for enhancement of these features will be foreclosed by the inability to test.<sup>51</sup>

RRW advocates claim that both designs make revolutionary advances in safety and use control despite the lack of testing. At the same time, in response to the congressional goal of minimizing the likelihood of a return to testing, the designs exclude some innovative designs that might further increase safety and use control but that are not mature enough to be used without testing.

**7. Reduce the consequences of an accident or attempted unauthorized use that does not produce nuclear yield. [2, 3, 4, 5, 7]** Insensitive high explosive (IHE) is much less likely to detonate than is the conventional high explosive (CHE) used on W76 and W88 warheads for submarine-launched ballistic missiles. Accidental detonation of IHE or CHE would almost surely not result in a nuclear detonation, but IHE would reduce the risk to production workers, military personnel, and the public from a nonnuclear explosion and the plutonium it would scatter. The first RRW, RRW-1, would be used in place of some W76s. Its design seeks to create the W76’s military capabilities in a larger, heavier package, and uses some of that extra weight and volume for IHE. RRW’s supporters point to the use of IHE as an advantage of RRW.

The reduced sensitivity of IHE comes at a price: IHE is less energetic than CHE, so a warhead requires more IHE than CHE to initiate the nuclear explosion. While the designs for the first RRW use IHE, the W76 uses CHE, so the W76 LEP must also use CHE. As a result, a requirement to use IHE would force a switch from W76 LEP to RRW. LEP supporters recognize that IHE would improve safety in some accident scenarios, but note that the W76 has not had a single accidental detonation of its high explosive since its deployment in 1978, and that the Navy has high confidence in the W76 LEP. Accordingly, they see the drawbacks of moving to RRW as outweighing the safety benefits of moving to IHE.<sup>52</sup>

<sup>50</sup> S.S. Hecker, “Answers to Senator Kyl’s questions,” attachment to letter from S.S. Hecker, Director, Los Alamos National Laboratory, to Honorable Jon Kyl, September 24, 1997, in U.S. Congress. Senate. Committee on Governmental Affairs. Subcommittee on International Security, Proliferation, and Federal Services. *Safety and Reliability of the U.S. Nuclear Deterrent*. Senate Hearing 105-267, 105<sup>th</sup> Cong., 1<sup>st</sup> sess., 1997, p. 84.

<sup>51</sup> “Prepared Statement by Dr. C. Paul Robinson,” in U.S. Congress. Senate. Committee on Armed Services. *Comprehensive Test Ban Treaty*. Senate Hearing 106-490, 106<sup>th</sup> Cong., 1<sup>st</sup> sess., 1999, p. 130.

<sup>52</sup> For further discussion, see U.S. Congress. House Committee on Armed Services, Panel on Nuclear Weapons Safety, *Nuclear Weapons Safety*, Committee Print No. 15, 101<sup>st</sup> Cong., 2<sup>nd</sup> sess., p. 26-33, by Sidney Drell, Chairman, John Foster, Jr., and Charles Townes; and (continued...)

## Warhead Characteristics: Design for Manufacturing and Maintenance

When the laboratories developed warheads now in the stockpile, they gave such characteristics as cost, ease of manufacture, and ease of dismantlement secondary consideration at best. While there was some consultation with the plants, the priority was “physics first.” In order to minimize weight, designers would use materials that were hazardous, difficult to machine, or that produced massive waste streams, and would call for hard-to-manufacture components and features. With the emergence of SSP in the early 1990s and LEPs in the mid-1990s, the labs began to work much more closely with the plants. With congressional RRW goals bearing on ease of manufacture, cost, reduced use of hazardous material, and the like, both design teams have collaborated intensively with the plants on how to make designs safer and easier to manufacture, and have included some such features in the designs. More broadly, teams and plants considered all aspects of a warhead’s life cycle in developing the CCRDs. Note that many features under this heading lower costs, and that designing warheads for safety of manufacture often makes for easier manufacturing.

**8. Reduce the environmental burden imposed by warhead production.** [3, 4, 7] This goal seeks to reduce waste streams and potential harm to the environment, and to improve worker safety. But it is much more than “just green.” It contributes to other goals, such as making manufacturing easier and reducing cost. For example, some current warheads use beryllium, which is toxic and difficult to machine; neither RRW design uses beryllium. Both teams claim that new RRW manufacturing processes will potentially reduce radioactive waste, and expect that RRW nuclear explosive packages will reduce hazardous material usage. In contrast, NEP components in LEPs must replicate, insofar as possible, original specifications, including use of hazardous materials.

RRW’s critics recognize that RRW should be able to meet this goal, but argue that LEP might meet it in other ways. LEPs could retain existing pits, reducing hazardous material usage, while RRWs, at least for missiles, probably would require new pits. Nonnuclear components, whether for LEPs or RRWs, could use equally benign materials. NNSA could augment efforts to reduce waste in support of LEP.

**9. Design warheads for safety of manufacture.** [2] Both teams worked closely with the plants to minimize the production steps needed. Both designs are expected to eliminate roughly 1/3 of these steps through process simplification, which in turn is expected to reduce worker radiation exposure and the waste stream dramatically. Pantex states,

10 CFR 830 requires a more formal Documented Safety Analysis and documented weapon response from the design agencies, safety requirements/controls have increased at Pantex as a result. Tighter safety requirements can restrict throughput. The design of both CCRDs has, from the

<sup>52</sup> (...continued)

CRS Report RL32929, *Nuclear Weapons: The Reliable Replacement Warhead Program*, by Jonathan Medalia, section titled “Might RRW Enable an Increase In Warhead Safety?”

beginning, addressed safety concerns with a view to meeting Pantex safety requirements and optimizing production.<sup>53</sup>

The use of IHE in the Competing Candidate RRW Designs (CCRDs) shows how improved safety can facilitate manufacture. Pantex has “bays” and “cells” for assembling and disassembling warheads. Bays and cells are reinforced-concrete rooms; cells are designed for a higher level of containment and, therefore, for more dangerous operations. At Pantex, 39 assembly bays and 7 cells are authorized to perform nuclear explosive operations, so the requirement to use cells for operations involving CHE and plutonium limits throughput.<sup>54</sup> Because IHE is so much safer to handle, work with IHE and plutonium can be done in bays as well as cells.

RRW advocates state that LEPs require manufacturing with hazardous materials and complex processes that RRWs eliminate. LLNL states that its new process for fabricating RRW pits reduces radiation waste 10-15 percent and worker radiation exposure 15-20 percent, and that the CA design replaces hazardous materials used in several components with materials that are non-hazardous and commercially available. The risk of safety issues, in this view, is higher for LEPs than RRWs.

“Optical isolation” provides another example of how a new approach can improve ease and safety of manufacturing. An enormous concern at Pantex is that electrostatic discharge (ESD) — a spark, such as from static electricity or lightning — could detonate CHE in a primary, potentially killing workers and scattering plutonium. This concern has in the past caused Pantex to halt operations, sometimes for months. Guarding against it is difficult; for example, the steps to move a CHE component within Pantex take four hours because of the need to protect against ESD. The NM design includes a technique called “optical isolation,” which would interrupt a direct electrical detonation path to a warhead’s detonators. Pantex states that this approach, if successful, would “reduce or eliminate the need for ESD controls.”<sup>55</sup>

Kent Fortenberry, Technical Director of the Defense Nuclear Facilities Safety Board,<sup>56</sup> provided CRS with the following comments on safety aspects of RRW:

Although the Board can point to areas where significant incremental improvements have been achieved in the safety of ongoing nuclear weapon operations, the RRW program represents the potential for a substantial step change improvement in safety.

<sup>53</sup> Information provided by Pantex Plant, September 19, 2006.

<sup>54</sup> Pantex plans to add three cells by the RRW FPU date (now planned for FY2012) through a cell upgrade program. Information provided by Pantex Plant, September 19, 2006.

<sup>55</sup> Information provided by Pantex Plant, September 19, 2006.

<sup>56</sup> The Defense Nuclear Facilities Safety Board was created by Congress 1988 “as an independent oversight organization within the Executive Branch charged with providing advice and recommendations to the Secretary of Energy ‘to ensure adequate protection of public health and safety’ at DOE’s defense nuclear facilities.” U.S. Defense Nuclear Facilities Safety Board. “Who We Are,” at [http://www.dnfsb.gov/about/index.html].

The Board has not reviewed the details of the RRW design proposals. It is possible that certain design attributes could introduce new hazards or safety concerns. In fact, the Board is aware of at least one design feature that is undergoing additional development to address a potential safety impact. However, the current RRW design proposals contain attributes that should provide a marked increase in the safety of nuclear weapon manufacturing, surveillance, maintenance, and dismantlement. Examples include design attributes that eliminate hazardous materials, reduce and simplify processing steps, reduce the required disassembly and inspection operations, and reduce waste streams. Other examples include design attributes that have the potential to mitigate or eliminate the impact of abnormal or accident conditions such as fire, electrostatic discharge, lightning, mechanical impact, and other scenarios that might create the potential for a high explosive violent reaction or inadvertent nuclear detonation.<sup>57</sup>

Critics hold that LEP might also increase safety. While all RRW components would have to be manufactured and assembled, critics maintain that LEPs manufacture and replace fewer components on average; some LEPs require complete, and others require partial, disassembly and reassembly.<sup>58</sup> Further, in this view, means other than RRW can improve safety. Safety of manufacture is constantly improving through better building maintenance, more worker training, and so on. Pantex states it has improved safety practices for handling high explosives, such as by reducing the number of times an explosive component must be lifted by hand, and has changed some solvents in response to an accident some years ago in which ESD was thought to have ignited a small fire in a flammable solvent.<sup>59</sup> Because of such steps and an increased focus on “safety culture,” it may be argued, the plants have very good and improving safety records. For example, NNSA stated that Pantex has never had an ESD event causing death or serious injury, though it has had ESD events that interrupted production, and Pantex stated that the last time a Pantex worker was killed or seriously injured by an accident involving CHE was in 1977.<sup>60</sup>

**10. Design warheads for ease of manufacture.** [4, 6, 7] Pantex wanted the designs to minimize assembly and disassembly steps. Both teams treated this as a design priority. They found that relaxing the requirement for a high yield-to-weight ratio simplified manufacturing. Further, in past practice, manufacturing tolerances of parts were driven to be the best achievable. In contrast, tolerances for CCRD components are arrived at by simulations that relate tolerances to performance. Relaxing tolerances makes manufacturing easier, reduces the number of units rejected, increases throughput, and reduces waste, all of which lower cost. Los Alamos provided two examples of how CCRDs could facilitate manufacturing.<sup>61</sup>

<sup>57</sup> Personal communication, Kent Fortenberry, Technical Director, Defense Nuclear Facilities Safety Board, September 14, 2006.

<sup>58</sup> Information provided by Pantex Plant, September 19, 2006.

<sup>59</sup> Information provided by Pantex Plant, September 15, 2006.

<sup>60</sup> Information provided by NNSA Pantex Site Office, December 11, 2006, and by Pantex Plant, September 19, 2006.

<sup>61</sup> Discussion with Los Alamos staff, September 15, 2006.

In manufacturing pits in the current stockpile, pits in process were taken from manufacturing stations to separate work stations to be measured and certified, a time-consuming process. In contrast, the higher margin of CCRDs is expected to permit tolerances to be relaxed enough to enable gauging and certification of pits in process on production machines. This reduces manufacturing time, cost, and floor space.<sup>62</sup>

The new process for manufacturing RRW pits will utilize a direct casting process that greatly reduces the required number of subsequent process steps.

The NM design also makes assembly and disassembly easier in other ways. It minimizes the use of adhesives, which add time and complexity to assembly because they must be cured for the proper time and at the proper temperature, and may prevent nondestructive disassembly. The NM design reduces part count, assembles nonnuclear components into subassemblies before delivery to Pantex, and reduces the number of assembly steps that must be performed in cells or bays. LLNL states that its new process for fabricating RRW pits holds the potential to increase manufacturing efficiency. It eliminates some manufacturing bottlenecks. It reduces the number of workstations and process steps by about 25 percent. LLNL has proposed replacing a major component that, for current warheads, was made on a mile-long production line with a new-design RRW component that could be manufactured commercially.<sup>63</sup>

Using less hazardous material makes manufacturing easier. For example, Pantex states, “before work can be done on explosives a Documented Safety Analysis must be established for safe operations. Developing and approving this basis constitutes a large portion of the workload at Pantex, and is simplified by the use of IHE.”<sup>64</sup>

Critics argue that LEP may offer manufacturing efficiencies. A November 2006 study, discussed below under Issues for Congress, has increased the estimate of minimum pit life from 45-60 years to 85-100 years or more. This estimate, if used as the basis for stockpile decisions, would defer the need for most pit production for LEPs. The vast majority of warhead components are nonnuclear; manufacturing improvements for them can be made equally for LEP or RRW. Ease of manufacture for RRWs compared to LEPs depends on the warhead to be life-extended. If a warhead has IHE, good margins, limited hazardous material, and better than average safety and use control, and does not require a new pit, then the LEP may involve less manufacturing difficulty than an RRW. If the LEP involves CHE and other hazardous materials, no clear statement can be made about relative manufacturing effort.

**11. Design warheads for ease of maintenance. [6]** For current warheads, the practice has long been to remove 11 units of each warhead type per year from fielded weapon systems. These units are disassembled at Pantex and

<sup>62</sup> [Note by CRS] Reduction in floor space for operations with nuclear materials is important because adding such space through new construction costs, by LANL’s estimate, \$30,000 per square foot.

<sup>63</sup> Information provided by Lawrence Livermore National Laboratory, November 27, 2006.

<sup>64</sup> Information provided by Pantex Plant, September 19, 2006.

surveilled throughout the Complex, imposing a burden on the Complex. This practice also imposes a burden on the Air Force and Navy, which must remove warheads from storage, silos, or submarines, send them to DOE, and replace them with spares. In contrast, both competing designs envision two surveillance removals per year, achieving this reduction through improved surveillance and non-destructive evaluations and through calibrated shelf life units. The latter are identical to deployed warheads, but the plants retain them. They are calibrated to fielded warheads in that they experience the same environments as fielded units relevant to particular aging phenomena. The documentation for each unit, from manufacturing onward, will also be much more comprehensive than for warheads now in the stockpile.<sup>65</sup>

Laboratory sources indicate that both teams are also considering embedding sensors inside warheads to provide data on a warhead's environmental conditions, such as temperature, vibration, and hydrogen level, which help estimate performance and lifetime, and on deterioration, such as cracking or corrosion. Other sensors would report on a weapon's status, such as if valves are in their expected configuration. They would not replace surveillance, but would increase the amount and types of data that can be gathered by nondestructive means and reduce the disassembly required for surveillance. No decision has been made on using these sensors. The competing designs also have characteristics that make disassembly easier, such as modular design and minimal use of adhesives. Warheads are disassembled not only at the end of their service lives to remove them from the stockpile, but also for surveillance, repairs, and other maintenance, so ease of disassembly is important throughout a warhead's service life.

Critics assert that some RRW techniques for ease of maintenance might be applied to current warheads, such as replacing limited-life components (like batteries) in current warheads with limited-but-extended-life components being developed for RRWs. They note that the current stockpile has calibrated shelf life units, so this is not a new advantage for RRW. They fear that data from onboard sensors may not lead to correct diagnosis of warhead problems. Commenters pointed to an instance decades ago in which a part made of one material was destroyed by vapor normally released by another part, forcing a change of the material used to fabricate the first part. One commenter asks if embedded sensors would have understood the vulnerability of the original component. Robert Peurifoy, former Vice President of Technical Support, Sandia National Laboratories, Albuquerque, NM, states, "It is my opinion that the best way of searching for material incompatibilities is by conducting accelerated aging tests."<sup>66</sup> The critics' greatest concern with the RRW surveillance plan is that while examining fewer warheads each year would reduce the surveillance burden, it would also reduce the sample size on which reliability estimates are based, reducing confidence in reliability.

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<sup>65</sup> Information provided by Lawrence Livermore National Laboratory, July 27, 2006, and Los Alamos National Laboratory, September 15, 2006.

<sup>66</sup> Email, September 1, 2006. These tests subject warheads from the stockpile, as well as components and materials, to high temperature and temperature cycling, generally for a year or more, to speed up the aging process so as to gain early warning of potential deterioration.

**12. Increase warhead longevity.** [1] RRW may increase longevity somewhat. For example, some current warheads use exotic materials with undesirable aging properties, while the competing designs use some materials with longer expected life. Also, making surveillance and disassembly easier should make it easier to detect and repair problems.

Long service life, however, is not a prime concern of the program and does not appear to be an advantage of RRW over LEP. NNSA's vision of the Complex of 2030 calls for "a continuous design/deployment cycle that exercises design and production capabilities ..."<sup>67</sup> Under this plan, RRWs might stay in service for two or three decades, comparable to the originally-anticipated service lives of current warheads, rendering RRW longevity moot. LLNL states, "Supporters of RRW also do not claim that RRW will provide significant improvement in warhead longevity. Current warheads typically last two or three decades, and with LEP can be made to last two or three decades longer. RRW may make some improvement on that, especially for some key hard-to-manufacture components, but this is not a major feature of the program."<sup>68</sup> NNSA states:<sup>69</sup> "NNSA developed the LEP Program to extend the stockpile lifetime of a warhead or warhead components at least 20 years with a goal of 30 years." "The B61 LEP will extend the life of the B61 for an additional 20 years." "The W76 LEP will extend the life of the W76 for an additional 30 years." As noted, the Navy has high confidence in the W76 LEP.

Experts on both sides agree that SSP, surveillance, and LEPs have extended the life of current warheads and can continue to do so. They disagree on how long LEP will be able to maintain high confidence in current warheads, though the argument is hypothetical on both sides. Those favoring RRW argue that unexpected degradations might arise that will be beyond the ability of SSP to anticipate, and of LEP to resolve, in a timely manner. LEP's supporters feel that as SSP improves, the ability to predict problems and maintain warheads will also improve and the range of unanticipated problems that could cause LEP to fail will diminish.

## Stockpile Characteristics

**13. Fulfill current mission requirements of the existing stockpile.** [2] RRW-1 would have a yield within 1 or 2 percent of that of the W76.<sup>70</sup> It would be placed in the Mk5 aeroshell, now used only for the W88 warhead, instead of the Mk4, which carries the W76. The Mk5 provides somewhat more accuracy than the Mk4, offsetting any loss of effectiveness from a slight yield reduction of the RRW, so that the RRW/Mk5 could fulfill W76/Mk4 mission requirements.

<sup>67</sup> U.S. Department of Energy, National Nuclear Security Administration, Office of Defense Programs. *Complex 2030: An Infrastructure Planning Scenario for a Nuclear Weapons Complex Able to Meet the Threats of the 21<sup>st</sup> Century*, DOE/NA-0013, October 2006, p. 9.

<sup>68</sup> Information provided by Lawrence Livermore National Laboratory, September 19, 2006.

<sup>69</sup> Department of Energy, *FY 2007 Congressional Budget Request*, Volume 1, p. 79.

<sup>70</sup> Testimony of General James Cartwright, USMC, Commander, U.S. Strategic Command, in U.S. Congress. House. Committee on Armed Services. Subcommittee on Strategic Forces. Hearing on the U.S. Strategic Command, March 8, 2007.

**14. Avoid requirements for new missions or new weapons. [5, 6, 8]**

RRW-1 would replace existing warheads with new-design warheads that can perform current missions using existing aeroshells and missiles. At the same time, RRW-1 is not tailored for new missions that have concerned some in Congress. It does not rely on new physical principles for the nuclear explosion, and is not designed to produce new nuclear effects such as electromagnetic pulse. The design goal for RRW-1 is to match the yield of the W76, which it replaces. RRW-1 will not be a low-yield “mini-nuke.” Nor will it be a “bunker buster,” or earth penetrator, and the competing designs did not have the ruggedness needed for that purpose.

LEP’s supporters point out that retaining existing warheads through LEPs would avoid new ones. Whether existing warheads would be used for new missions would be a political and military decision. Others favor having the ability to modify existing warheads, or to develop new ones, for new missions. In this view, the ability to respond to potential future threats is essential, and can most surely be met through resumed nuclear testing.<sup>71</sup>

**15. Focus initial efforts on replacement warheads for submarine-launched ballistic missiles (SLBMs). [3]** Several rationales are stated for this goal. (1) The W76 is the most numerous warhead in the stockpile, so its failure would severely weaken the U.S. deterrent force. Using RRWs, life-extended W76s, and W88s would reduce that risk. (2) The W76 is old, first deployed in 1978. (3) If the current number of W76s is retained, production schedules would place RRW-1 in competition with the W76 LEP for Complex resources. Planning for RRW-1 to substitute for some W76 LEP production could lessen that competition.

The RRW designs respond to this goal by packaging the military capabilities of the W76 into a design that can be used in the Mk5. The designs were required to maintain the same weight, center of gravity, and other characteristics of the W88 so RRWs could be used in the Mk5. DOD insisted on this approach to avoid the time and expense of building and flight testing new aeroshells or missiles for the Navy.

Supporters of LEP argue that W88s hedge against failure of the W76. They state that the W76 LEP, with the first production unit scheduled for FY2007, will provide an SLBM warhead with an established pedigree, and note that NNSA expects that the LEP will extend the warhead’s life by 30 years.<sup>72</sup> They ask why the Navy would want to use a new, untested warhead to replace one that has been in the inventory for nearly three decades, that is supposed to be effective for decades more, and for which maintenance and handling procedures are well understood. DOD and DOE have both invested heavily in the LEP so that, in this view, completing the full

<sup>71</sup> Information provided by Robert Barker, former Assistant to the Secretary of Defense for Atomic Energy, November 29, 2006.

<sup>72</sup> U.S. Department of Energy. Office of Chief Financial Officer. *FY 2007 Congressional Budget Request*. Volume 1, National Nuclear Security Administration. DOE/CF-002, February 2006, p. 79, at [[http://www.mbe.doe.gov/budget/07budget/Content/Volumes/Vol\\_1\\_NNSA.pdf](http://www.mbe.doe.gov/budget/07budget/Content/Volumes/Vol_1_NNSA.pdf)].

W76 LEP production is the most cost-effective way to provide SLBM warheads needed for the stockpile. Barry Hannah, Chairman of the RRW POG, stated,

The W76 LEP that is currently underway is an excellent program in terms of technology, schedule, and cost. I believe it meets the Navy's needs. While it makes many changes and some upgrades to components, it also includes changes that increase margins in order to compensate for problems or uncertainties that component changes or age-related degradation might introduce.<sup>73</sup>

**16. Complement or replace LEP.** [2] Supporters hold that RRWs would complement LEPs very well. Current warheads were designed with the help of an extensive nuclear test program, were designed to meet Cold War requirements, and have been repeatedly certified without nuclear testing to be safe and reliable, but they cannot be modified to meet the many congressional goals discussed here. In contrast, RRWs would not be tested, would be designed to meet post-Cold War requirements, arguably could be certified without nuclear testing to be safe and reliable, and could, as a result of using a new design, meet congressional goals.

DOD, NNSA, and political leaders could in the future decide to replace current warheads instead of having them undergo LEPs. Any such decision would hinge on the success of the RRW program and LEP, the perceived need for nuclear weapons, and the willingness of Congress and the Administration to support such replacement. It is thus premature to speculate on whether RRWs will replace current warheads.

The Air Force raises questions about the effectiveness of LEPs, and makes the following assertions:

- LEPs are complicated. Current warheads were not designed to be refurbished, so disassembly is difficult.
- Some LEP components are made with archaic processes and hazardous materials.
- LEPs are time-consuming. The Air Force was convinced by 1992 that the W87 ICBM warhead needed certain changes, and the Secretary of the Air Force sent a letter to the Secretary of Energy in that year asking DOE to make the changes. It took until 1999 for DOE to deliver the FPU to the Air Force.
- It is preferable not to rely on old warheads, though the first B61 has been in the stockpile since 1968. Warheads deteriorate over time, and a warhead in good condition now might, it is argued, suffer severe corrosion and become unreliable in 10 or 15 years.
- Margins in some current warheads were thin by design, and a series of changes could erode confidence that the margin remained sufficient.

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<sup>73</sup> Information provided by Dr. Barry Hannah, SES, Branch Head, Reentry Systems, Strategic Systems Program, U.S. Navy, telephone conversation with the author, October 23, 2006.

- The foregoing factors raise questions about whether DOD can have confidence in the ability of the Complex to execute LEPs as a long-term sustainment strategy.<sup>74</sup>

Critics expect that LEP will enable NNSA to maintain current warheads for many years. As noted under Goal 15, a Navy official shared this view in the case of the LEP for the W76. Critics recognize that it may be costly to bring back out-of-date processes and hazardous materials, but argue that cost must be weighed against the cost of designing, producing, and deploying perhaps thousands of RRWs and against the uncertainties arising because RRWs will not undergo nuclear tests.

**17. Reduce the number of nondeployed warheads. [2, 4, 5, 6]** The President approves the number of U.S. warheads annually in the Nuclear Weapons Stockpile Memorandum. The number of deployed warheads depends on perceived military and political needs. DOD also retains many nondeployed warheads to hedge against technical and geopolitical risk. The former arises from the prospect that an existing warhead type might develop a defect that NNSA would have difficulty remedying. Geopolitical risk arises from the prospect that the Complex could not manufacture new warheads fast enough to respond to such threats as a major expansion of an adversary's nuclear forces.

RRW's supporters claim that RRW would permit a reduction in nondeployed warheads for several reasons: RRWs would be less likely to develop defects because of increased margins; defects could be corrected more easily because RRWs would be designed for ease of surveillance and disassembly; a modified Complex could produce RRWs in time to respond to threats because they would be designed for ease of manufacture, and fewer types of warheads would be needed as backups. Regarding the latter point, at least two warhead types are currently available for each delivery system. This approach hedges against the prospect that a failure of one warhead type would render an entire delivery system unusable until the problem was fixed, impairing the U.S. deterrent. Each warhead, however, is designed for use on only one type of delivery vehicle. In contrast, RRWs designed for one delivery system could be used on another. While the first RRW is designed for use on SLBMs, RRW supporters point out that it is designed so it could fit into ICBM aeroshells<sup>75</sup> with slight modifications, such as adjusting ballast. Using this approach, an RRW intended for SLBMs could back up ICBM warheads, and vice versa, and an RRW for cruise missiles could back up gravity bombs, and vice versa.

LEP supporters reject the argument that many nondeployed warheads are needed to hedge against technical problems. In their view, surveillance and life-extension programs have shown a continually-improving ability to find and fix problems. They expect that too few RRWs would be built to arm both the intended and alternate delivery vehicles because building enough to arm both would be at odds with the goal of fewer nondeployed warheads. But LEP supporters believe it makes sense to

<sup>74</sup> This paragraph is based on information provided by a senior Air Force official, interview with the author, September 26, 2006.

<sup>75</sup> These aeroshells are the Mk12A, which carries the W78, and the Mk21, which carries the W87.

retain nondeployed warheads to hedge against geopolitical risks not detected in time by intelligence. In their view, a modified Complex building RRWs could not compensate for that risk if the nondeployed stockpile were to be reduced sharply. They also express concern that having fewer warhead types would magnify the consequences of a failure of one such type.

## Nuclear Weapons Complex

Congress has been concerned for decades about the size, efficiency, and cost of the Complex. At issue are how to RRW and LEP will bear on upgrading the Complex and maintaining its skill base.

**18. Support upgrading of Complex capabilities. [2, 3, 4, 5, 6]** For decades, analysts have noted the poor condition of the production plants, which have many buildings dating from World War II. Secretary of Defense Donald Rumsfeld wrote, “Since the end of the Cold War, ... our nuclear infrastructure has atrophied. ... it needs to be repaired to increase confidence in the deployed forces, eliminate unneeded weapons, and mitigate the risks of technological surprise.”<sup>76</sup> He noted that the Nuclear Posture Review of 2001 called for a responsive infrastructure as part of its New Triad. General James Cartwright, Commander, U.S. Strategic Command, stressed the importance of this proposed upgrade: “an efficient and more responsive nuclear weapons infrastructure ... is the essential element needed to ensure our weapons are safe, secure, and reliable, to ensure we can respond to both technological and political surprise, and to reduce our current stockpile of nuclear warheads.”<sup>77</sup>

Thomas D’Agostino, NNSA Deputy Administrator for Defense Programs, said, “We have worked closely with the DoD to establish goals for ‘responsiveness,’ that is, timelines to address stockpile problems or deal with new or emerging threats. For example, our goal is to understand and fix most problems in the stockpile within 12 months of their discovery.”<sup>78</sup> To meet these goals, the Secretary of Energy Advisory Board’s Task Force on the Nuclear Weapons Complex Infrastructure, and NNSA in its “Complex 2030,” have proposed alternative plans.<sup>79</sup> While they differ in specifics, both would consolidate fissile material, eliminate some redundancies in R&D facilities, and consolidate elements of the current Complex. Both assume Complex

<sup>76</sup> U.S. Secretary of Defense. “Nuclear Posture Review Report: Foreword.” January 10, 2002, p. 3, at [<http://www.defenselink.mil/news/Jan2002/d20020109npr.pdf>].

<sup>77</sup> General James Cartwright, Commander, U.S. Strategic Command, “Statement Before the Strategic Forces Committee, Senate Armed Services Committee, on Global Strike Plans and Programs,” March 29, 2006, p. 13-14; available at [<http://armed-services.senate.gov/statemnt/2006/March/Cartwright%20SF%2003-29-06.pdf>].

<sup>78</sup> “Statement of Thomas P. D’Agostino ...,” April 5, 2006, p. 4.

<sup>79</sup> For the Task Force plan, see U.S. Department of Energy. Secretary of Energy Advisory Board. Nuclear Weapons Complex Infrastructure Task Force. *Recommendations for the Nuclear Weapons Complex of the Future*, 2005. For NNSA’s plan, see U.S. Department of Energy. National Nuclear Security Administration. Office of Defense Programs. *Complex 2030: An Infrastructure Planning Scenario for a Nuclear Weapons Complex Able to Meet the Threats of the 21<sup>st</sup> Century*, DOE/NA-0013, October 2006.

reconfiguration completed around 2030, and a Complex-in-transition supporting a stockpile-in-transition. Even if the United States proceeds with RRW, the Complex would, for decades, need to support current warheads and RRWs simultaneously.

Opinions differ on the link between RRW and a responsive infrastructure. RRW's supporters maintain that RRW would permit a more efficient Complex. They assert that it would take fewer steps to make NEP components for RRWs than for LEPs, simplifying production. Looser tolerances would result in fewer rejected parts. Modular designs and elimination of conventional high explosives would permit greater throughput at Pantex. Reducing hazardous materials, it is argued, would enable more manufacturing to be done away from the most costly floor space and might permit more work to be contracted out. Each design eliminates at least one hazardous materials production unit, enabling fewer and smaller facilities to treat waste from production. In contrast, supporters claim, LEP locks the Complex into existing designs, materials, and processes.

LEP's supporters note that NNSA routinely upgrades the Complex, such as by introducing new manufacturing processes, to support LEP. Further, it has for several years received funds for the Facilities and Infrastructure Recapitalization Program, with an FY2008 request of \$293.7 million, to improve the Complex. While RRW might permit a more capable Complex by increasing efficiency, LEP might require less new capability and capacity. For example, LEP's supporters question the advantage of dismantling thousands of warheads while building facilities able to manufacture large numbers of RRWs to respond to a threat. They ask if it might be more responsive to maintain existing warheads than to add that capacity. Further, they argue, if DOD needed a few new-design warheads to attack specified targets, the laboratories could probably build them using their current facilities.

Some recognize the need to modernize the aging production plants but question if modernizing the Complex around RRW is the right approach. They argue that narrowing the range of materials that the Complex can handle, such as by eliminating CHE and some toxic materials, make the infrastructure less capable and thus less responsive. They fear that streamlining the Complex with fewer warhead types and modular warhead design reduces the diversity of its workload while increasing the risk of a failure affecting much of the nuclear stockpile.

**19. Exercise skills of the Complex.** [2, 3] DOE, NNSA, and Complex staff feel strongly that it is imperative to exercise the complete set of skills in the Complex in order to maintain them, and state that the RRW program will do this while LEP does not. According to DOE,

The complete set of skills is required to protect against technological surprise as well as to have the capability to design a weapon with new military characteristics, should it be required. The RRW design program looks at the overall weapon design, not just those few components that get replaced in an LEP. Additionally, the RRW has provided the opportunity to develop safety,

security, and use control features; this cannot be done for an LEP which is limited to extending the life of the existing design.<sup>80</sup>

According to Sandia,

By exercising all of the skills and capabilities required to design, test, qualify, and produce complete systems on a regular basis, those skills are ready and available to address higher-priority problems on a moment's notice. The Complex must exercise all of the skills required, not just the science, modeling, and simulation skills, to have them available. These skills include but are not limited to a strong scientific foundation, systems analysis, engineering analysis, design definition, systems engineering, component design, test and evaluation, component production, and weapon assembly and disassembly. Like an athlete, you cannot exercise 20 percent of the skill base and expect to function at 100 percent on game day. You have to practice all parts of your craft or you will not be able to perform up to expectation when a problem arises unexpectedly.<sup>81</sup>

Livermore provided the following response, with which Los Alamos concurs:

One of the central goals of RRW is to enable the nuclear weapons complex to be more responsive to future unforeseen problems. ... Because RRWs are designed to be easier to manufacture, certify, and maintain, they can make the complex more responsive. When problems arise, the complex will have the demonstrated capability to replace problem warheads with more reliable and maintainable warheads. Thus risk mitigation can be borne by the infrastructure rather than by the large inventory of reserves. Whatever problems arise, a complex and work force that is experienced and capable of producing and fielding warheads that meet the needs of the day rather than dedicated to perpetuating the designs of another era has a better chance of being able to respond.<sup>82</sup>

NNSA prefers a continuous cycle of design and deployment, as noted, in part to exercise Complex capabilities, rather than conducting LEPs of RRWs in the future. Similarly, a SEAB Task Force argued for an ongoing program of RRW design and production on a five-year cycles.<sup>83</sup> In discussions with CRS in September 2006, a task force member argued that this approach, by using the latest design and production methods rather than sustaining old technologies, would aid recruitment, retention, and capability development in the Complex workforce. LANL claims that RRW would exercise design skills better than LEP. Because RRW is a new design, designers must confront the full range of tradeoffs simultaneously, balancing yield, weight, ease of manufacture, cost, use control, safety, reduction of hazardous material, etc. In contrast, LANL argues, an LEP constrains choices for the nuclear explosive package because replication is required to minimize divergence from parameters that were validated by nuclear testing.

<sup>80</sup> Information provided by NNSA, August 11, 2006.

<sup>81</sup> Information provided by Sandia National Laboratories (NM), July 25, 2006.

<sup>82</sup> Information provided by Lawrence Livermore National Laboratory, July 26, 2006.

<sup>83</sup> U.S. Department of Energy. Secretary of Energy Advisory Board. Nuclear Weapons Complex Infrastructure Task Force. *Recommendations for the Nuclear Weapons Complex of the Future*. July 13, 2005, p. 13.

LEP's advocates respond: (1) LEP exercises skills. Design expertise is needed to ensure that a minor change introduced by an LEP will not create a problem, such as a material incompatibility, elsewhere in the warhead. Production expertise is needed in making replacement components and exchanging new for old components. Certification expertise is needed to ensure that a life-extended warhead will meet safety, reliability, and other requirements. A report by the AAAS states, "Although life extension is not equivalent to executing a new design, it nonetheless employs many of the same tools, processes, and disciplines."<sup>84</sup> (2) Most warhead problems, they claim, will be discovered after several decades, and current warheads are very well understood, so unforeseen problems are less likely for LEP than for RRW. (3) Retaining and maintaining many inactive warheads provides a more timely hedge than counting on a Complex in transition to produce enough RRWs. (4) While its supporters claim RRW would be easier to maintain over the long term, it is inconsistent for them to argue that RRWs will have long service lives yet that RRWs should be replaced on an ongoing basis.

LEP proponents argue that NNSA could maintain the ability to design and produce new warheads by designing new warheads, producing them in small quantities, and not deploying them, thereby avoiding reliability risks and production costs of introducing new warheads into the stockpile. RRW supporters respond that it would be costly to design new warheads and develop production and certification processes for small builds as a skill maintenance program. They see this approach as far less effective than a program to deliver actual warheads to DOD. LEP proponents point out that it would be less costly to build small rather than large lots, and that large builds would impose on DOD the cost to replace many warheads and on DOE the cost to dismantle or store returned warheads.

## Cost

**20. Reduce life cycle cost. [2, 4, 5, 6, 7, 8]** There are no estimates for the total cost of the RRW program, or even for developing, manufacturing, and deploying RRW-1. Because the program is in early stages, there are many unknowns that will affect cost, such as design and production details and the number to be procured. Nonetheless, RRW's supporters assert that many aspects of the competing RRW designs are intended to reduce cost.

- The designs emphasize ease of manufacture and assembly, and use of safer and less costly materials.
- RRW should lower surveillance costs. The legacy stockpile consists of eight basic designs and many modifications within each design. Surveillance data for each are required. An RRW-based stockpile, it is argued, would have far fewer basic designs and modifications. Further, surveilling each warhead type would be less costly. The plan is to withdraw fewer units for surveillance, and embedded sensors, if used, could report on a warhead's condition without requiring disassembly.

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<sup>84</sup> American Association for the Advancement of Science, "The United States Nuclear Weapons Program: The Role of the Reliable Replacement Warhead," p. 23.

- Enhanced use-control features would permit a modification of physical security practices, perhaps slowing the growth of security costs.
- Increased design margins should make RRWs more tolerant of design or manufacturing flaws, or of changes due to aging or other causes. As a result, designers might be able to judge that a corrective action was not needed to fix certain problems, lowering maintenance cost.
- Ease of disassembly and reduction of hazardous materials would reduce cost of final dismantlement and any disposal of components when an RRW is to be retired.
- RRW costs should be more predictable than those of LEPs because LEPs must use some archaic technologies that will become increasingly difficult to maintain, while RRWs would have all-new components.
- RRW, by permitting DOD to have fewer nondeployed warheads, would result in fewer units undergoing LEPs or routine maintenance.

LEP supporters counter that LEP costs are more predictable because LEP would maintain warheads with which the Complex has considerable experience. They argue that extending the life of existing warheads would reduce manufacturing costs, avoid costs of training and equipment needed to handle new warheads, and postpone for decades the retirement of thousands of warheads. They note that LEPs consume a small fraction of the total stockpile stewardship budget, for example \$238.7 million (requested), or 3.7 percent, for FY2008. Another program, Stockpile Systems, involves routine maintenance of warheads. Its FY2008 request is \$346.7 million, or 5.4 percent of the stewardship budget. LEP supporters doubt that RRW could reduce these costs by much, especially because they expect the large body of relevant experience to hold down costs for maintaining or life-extending current warheads.

Advocates of LEP wonder when savings that RRW might yield might offset the large investment costs. They note an AAAS report stating, “an RRW program would likely add to costs in the near term, and it is not yet possible to determine when (and whether) the RRW could lead to savings in the long term.”<sup>85</sup> They see any savings from fewer nondeployed warheads as at risk if more RRWs must be built to respond to unforeseen threats. They note that adjusting costs and savings for net present value, taking into account the time value of money by placing heavier weight on costs and savings early in a project’s life, would delay reaching that point.<sup>86</sup> A second LEP of a current warhead years hence might cost less than the first because the certification procedures, manufacturing processes, equipment, and materials needed for the first LEP could be used in subsequent LEPs if the items to be repaired were identical. They argue that RRW maintenance costs would be nonnegligible if RRW had birth defects. They cite another AAAS statement, “The panel heard no

<sup>85</sup> American Association for the Advancement of Science, “The United States Nuclear Weapons Program: The Role of the Reliable Replacement Warhead,” p. 25.

<sup>86</sup> For further information on net present value, see U.S. Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, “Contract Pricing Reference Guides,” at Defense Procurement and Acquisition Policy website, [<http://www.acq.osd.mil/dpap/contractpricing/vol2chap9.htm>].

quantitative analysis that enhanced surety features in the RRW designs would be sufficient to substantially reduce the current reliance on guns, guards, and gates for the security that governs the work in most parts of the complex.”<sup>87</sup>

It does not appear that reducing the number of nondeployed warheads in storage would generate large savings for DOD. In response to a CRS question to the Air Force about the annual cost of maintaining its non-deployed warheads, the Air Force responded, “Most AF costs are associated with overall manpower, support equipment and facilities. The majority of these overhead costs do not vary directly in proportion to the quantity of weapons on hand.”<sup>88</sup> A senior Air Force official stated that storage of nuclear weapons is a fixed cost, with the size of the security force driven by storing nuclear weapons, not by the number of weapons. Nor did this individual see RRW resulting in fewer storage sites.<sup>89</sup>

Cost will be a critical factor in the decision on LEP or RRW. Yet there are serious questions about the validity of any 30-year life-cycle projection, especially one with such great unknowns: what engineering details must be solved to move from a preliminary to a final RRW design, how many warheads must the Complex support, how would the Complex support a mixed force for decades while LEPs were being phased out and RRWs were being phased in, and what will the reconfigured Complex look like. Nonetheless, cost studies can be of value even if they are preliminary, or can provide only relative costs, or note uncertainties that must be resolved to produce a firmer cost estimate. The cost section of the RRW report that Congress mandated in the FY2006 National Defense Authorization Act (P.L. 109-163, Section 3111) will thus merit close attention.

## Issues for Congress

Several issues that bear on the future of the U.S. nuclear weapons enterprise cut across many of the goals listed above. This discussion presents some of them, along with questions that Congress may wish to consider.

**How much is enough?** Many of the 20 goals are of the “more is better” variety: more reliability, more longevity, more safety, more security, more ease of manufacture. Yet each goal, while beneficial, imposes costs. Incorporating multiple safety and use control features into RRWs would add costs. Some goals impose design constraints that make it harder to reach other goals. Safety and use-control features add to the complexity of CCRDs, which might slightly reduce reliability. In some cases, the benefits sought may be questioned. While the CCRDs avoid the Trinity exception, Congress may wish to ask how much weight should be given to that scenario. It has never led to an accidental nuclear detonation, but past

<sup>87</sup> American Association for the Advancement of Science, “The United States Nuclear Weapons Program: The Role of the Reliable Replacement Warhead,” p. 21.

<sup>88</sup> U.S. Air Force, “Answers to Questions from CRS on RRW,” September 25, 2006.

<sup>89</sup> Information provided by a senior Air Force official, interview with the author, September 26, 2006.

performance does not guarantee future results. In other cases, benefits might be adequately achieved by means other than warhead design, such as features and systems external to the warhead. Congress may want to review some of the key design tradeoffs and whether current warheads are good enough. For example, the CCRDs demonstrate how much safety and use control can be obtained; as a separate matter, it is up to Congress, along with NNSA, the Air Force, Navy, and others to decide how much safety and use control they want and what tradeoffs they are willing to accept to obtain it.

**Will the Department of Defense accept RRWs?** DOD has seemed split in its support for RRW. DOD's 2006 Quadrennial Defense Review gave it a mild endorsement:

The Department is working with the Department of Energy to assess the feasibility and cost of the Reliable Replacement Warhead and, if warranted, begin development of that system. This system could enable reductions in the number of older, non-deployed warheads maintained as a hedge against reliability problems in deployed systems, and assist in the evolution to smaller and more responsive nuclear weapons infrastructure.<sup>90</sup>

In contrast, the U.S. Strategic Command (USSTRATCOM), which operates U.S. nuclear forces, strongly supports RRW. General James Cartwright, USMC, Commander of USSTRATCOM, testified in 2006:

USSTRATCOM supports the Reliable Replacement Warhead (RRW) as the key to transforming our aging Cold War nuclear weapons stockpile. RRW will enhance our long-term confidence in the stockpile and reduce the need to retain high numbers of hedge weapons while exercising the people, science, technology base and facilities required for sustaining the nuclear weapons enterprise.<sup>91</sup>

Some concerns raised by DOD components are that handling and maintenance procedures, aeroshells, and links between missile and warhead that have been developed for current warheads might have to be changed if RRWs are introduced. Current warheads have been tested and are certified to work, and LEPs are expected to extend warhead life by 20 to 30 years. Why incur the added burden imposed by RRW? Others feel that RRWs will reduce this burden once they are deployed. Congress may wish to determine if DOD leadership strongly supports RRW at present, and if not why not.

**Will LEP or RRW better maintain warheads for the long term without nuclear testing, or is a return to testing required?** RRW advocates argue that minor changes from LEPs may reduce confidence in current warheads over the long term, while RRW designs should provide high confidence

<sup>90</sup> U.S. Department of Defense. *Quadrennial Defense Review Report*, February 6, 2006, p. 49.

<sup>91</sup> General James Cartwright, Commander, U.S. Strategic Command, "Statement Before the Strategic Forces Committee, Senate Armed Services Committee, on Global Strike Plans and Programs," March 29, 2006, p. 18; available at [<http://armed-services.senate.gov/statemnt/2006/March/Cartwright%20SF%2003-29-06.pdf>].

because they stay well within parameters defined by nuclear test data and have wider margins than current warheads. LEP advocates respond that current warheads have extensive nuclear test pedigrees, SSP has greatly improved understanding of weapons science, and NNSA states that LEPs can extend the life of current warheads by 20 to 30 years. In contrast, they feel that RRW breaks the link between testing and certification. Still others maintain that neither LEP nor RRW can provide confidence because both break the link to testing, LEP because of the many changes inevitably introduced and RRW because it will not be validated by testing. The only way to have confidence in the stockpile, this position holds, is to resume nuclear testing. A fourth possible view is that either LEP or RRW, despite their differences, could maintain weapons for the long term. CRS is aware of no advocates for this fourth position. Nonetheless, a mixed RRW-LEP force would be inevitable for some years if the United States moved to an all-RRW stockpile; having two types of warheads designed decades apart to meet different requirements would lower the risk that a single failure could put at risk much of the stockpile. Congress may wish to examine competing methods for maintaining a reliable stockpile, problems that might arise in deploying a mixed LEP/RRW force and how they might be addressed, and ramifications of maintaining a test moratorium or of resuming testing.

**Might there be gaps between current RRW designs and actual RRWs?** It is easy to think of the current designs as actual warheads. However, the designs are preliminary, with considerable detailed design work remaining. Some components might prove difficult to manufacture. Design defects might emerge. Congress may wish to ask NNSA about where gaps between the current designs and actual warheads might arise, and what the historical record indicates.

**How do pit issues bear on the choice between RRW and LEP?** A pit is the fissile core of a modern thermonuclear weapon. It typically consists of a hollow plutonium shell and other metal shells surrounded by chemical explosives. The plutonium shell is by far the most difficult and costly pit component to make, and is the only one discussed here.

For many years, Rocky Flats Plant (CO) was the only site that made pits certified for the stockpile, but it stopped making pits in 1989. NNSA has not made certified pits since then. At present, the PF-4 (plutonium facility-4) building in LANL's Technical Area 55 (TA-55) is producing W88 pits at a low rate, with a capacity of 10 pits per year expected by the end of FY2007.<sup>92</sup> The first pits are expected to be certified in FY2007. NNSA plans to complete work in FY2012 to increase PF-4's RRW pit production capacity to 50 certified pits per year, but does not plan to increase PF-4's capacity beyond that level.<sup>93</sup>

<sup>92</sup> "Statement of Thomas P. D'Agostino, Deputy Administrator for Defense Programs, National Nuclear Security Administration, Before the House Armed Services Committee, Subcommittee on Strategic Forces," April 5, 2006, p. 7.

<sup>93</sup> To deliver these pits, PF-4 would need a production rate of 80 per year. This excess capacity would allow for pits rejected because of defects, disassembled for inspection during production, retained for future surveillance, and held as spares. Information provided by NNSA, September 19, October 4, and November 2, 2006, and U.S. Department of Energy.

(continued...)

Pit life bears on the choice between RRW and LEP. Plutonium decays radioactively in ways that may eventually impair pit performance. Until recently, NNSA's best estimate of pit life was 45-60 years. However, a November 2006 study extended that estimate considerably. The study, by the JASON scientific advisory group, reviewed an assessment of pit life by LANL and LLNL and found:

The assessment demonstrates that there is no degradation in performance of primaries of stockpile systems [i.e., warheads] due to plutonium aging that would be cause for near-term concern regarding their safety and reliability. Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetimes of 100 years or less have clear mitigation paths that are proposed and/or being implemented.<sup>94</sup>

This pit life "extension" would seem to favor LEP. Pits of current warheads are difficult and costly to build, involve hazardous materials, and require elaborate safety and security precautions. It is difficult to certify a remanufactured pit of current design without nuclear testing; for example, LANL has spent several hundred million dollars and many years to certify the nuclear performance of the W88 pits that PF-4 is manufacturing. If existing pits could remain in the stockpile for decades to come, then there would be high confidence in them. DOD could have high confidence in life-extended warheads, and fewer pits would have to be manufactured for many decades, reducing LEP costs.

RRW's supporters respond that RRW offers many advantages over LEP, such as in safety, use control, and skill maintenance, as discussed earlier, independent of pit life. They argue that wide margins will increase DOD's confidence in RRW pits, and that RRW pits will cost less to manufacture than pits for LEPs.

Pit life also bears on an issue that Congress has grappled with for years, pit production capacity and the need for a new production facility. In the FY2006 budget cycle, Congress deleted funds for a Modern Pit Facility, with a capacity of 125 pits per year. NNSA argues that it needs more capacity than PF-4 offers. To that end, its preferred Complex, "Complex 2030," includes a Consolidated Plutonium Center (CPC) with a capacity of 125 pits per year. John Harvey, Director of NNSA's Policy Planning Staff, explained why that capacity is needed despite the pit life findings:

First, even with longer lifetimes, as the stockpile ages, we will need to replace considerable numbers of pits in stockpiled warheads. Second, even if pits were to live forever, we will require substantial production capacity in order to introduce, once feasibility is established, significant numbers of RRW warheads into the stockpile by 2030. We should not assume that RRW could employ pit reuse and still provide important efficiencies for stockpile and infrastructure

<sup>93</sup> (...continued)

"Notice of Intent to Prepare a Supplement to the Stockpile Stewardship and Management Programmatic Environmental Impact Statement — Complex 2030," in U.S. National Archives and Records Administration. Office of the Federal Register. *Federal Register*, Vol. 71, No. 202, October 19, 2006, p. 61734.

<sup>94</sup> R.J. Hemley et al., *Pit Lifetime*, JSR-06-335, MITRE Corp., November 20, 2006, p. 1, available at [[http://www.nukewatch.org/facts/nwd/JASON\\_ReportPuAging.pdf](http://www.nukewatch.org/facts/nwd/JASON_ReportPuAging.pdf)].

transformation. Finally, at significantly smaller stockpile levels than today, we must anticipate that an adverse change in the geopolitical threat environment, or a technical problem with warheads in the operationally-deployed force, could require us to manufacture and deploy additional warheads on a relatively rapid timescale.<sup>95</sup>

LEP supporters challenge each point. (1) The JASON study implies that NNSA would not need to replace large numbers of pits of current warheads for many decades. (2) LEP supporters recognize that the competing RRW designs use pits of new design and would require pits of new manufacture, and that production of 50 pits per year would hold deployment of RRWs to an extremely slow pace. However, they see this reasoning as self-justifying: the assumption that RRW will be introduced justifies a new pit facility, and a new pit facility makes it possible to introduce RRWs at an acceptable pace. In the view of LEP supporters, LEP, especially if existing pits are retained, permits the United States to delay a decision on RRW for decades. (3) LEP supporters see this argument as circular. RRW permits a reduction in the stockpile, while the possibility of a technical or geopolitical problem requires a larger pit capacity to build more RRWs if needed. Instead, LEP supporters would retain current warheads and maintain them with LEP and Stockpile Systems programs, thereby avoiding the need for RRW and a new pit facility while hedging against technical risks and geopolitical threats. They see these reductions in cost and risk as outweighing any benefits that might arise from having fewer nondeployed warheads.

RRW supporters advance other reasons for a new pit facility. More capacity would permit production of more than one pit type at a time, so NNSA could respond to problems that require rebuilding pits out of the planned sequence and to threats that require new-design pits. In contrast, it would be hard to manufacture several pit types concurrently in PF-4, and if a problem were discovered in a pit type in the stockpile, PF-4 might be unable to replace pits in time to prevent withdrawing some weapon systems from deployment. Since PF-4 was completed in 1978, it might prove less costly to build a new facility than to upgrade PF-4, as a recent example from industry indicates.<sup>96</sup> They doubt that PF-4 could accommodate increasingly stringent safety and security requirements, and note that TA-55 has problems meeting current standards.<sup>97</sup> Pit production capacity is critical for RRW regardless of pit aging. Since the first RRW will use new pits, production of 50 pits per year would make for a slow deployment of RRWs; converting the stockpile to RRWs would take decades.

<sup>95</sup> Email to “possibly interested folks,” November 29, 2006.

<sup>96</sup> A *Wall Street Journal* article found that Toyota was able to achieve a considerably lower cost per vehicle by building an automobile assembly plant from scratch, as compared to an older General Motors plant. Lee Hawkins, Jr., and Norihiko Shirouzu, “A Tale of Two Auto Plants — Pair of Texas Factories Show How Starting Fresh Gives Toyota an Edge over GM,” *Wall Street Journal*, May 24, 2006, p. B1.

<sup>97</sup> See, for example, U.S. Defense Nuclear Facilities Safety Board. “Memorandum for J. Kent Fortenberry, Technical Director, from C.H. Keilers, Jr., subject Los Alamos Report for Week Ending August 25, 2006,” August 26, 2006, 1 p., at [[http://www.dnfsb.gov/pub\\_docs/lanl/wr\\_20060825\\_la.pdf](http://www.dnfsb.gov/pub_docs/lanl/wr_20060825_la.pdf)].

RRW supporters argue that using certified pits from retired warheads in RRWs would permit faster introduction of RRWs whether NNSA uses PF-4 or CPC. LANL saw pit reuse as desirable for RRW in theory because it would avoid most problems and capacity limits of pit production and would save large sums. Nonetheless, it ruled out pit reuse for missile warheads because existing pits could not accommodate all the safety and use-control features in the RRW designs and because they would be harder to certify than RRW pits. Pit reuse might, however, be possible for an RRW bomb. Because bombs are larger and heavier than warheads, they permit a wider range of design tradeoffs to improve margin, safety, and use control. Reusing pits would make all the limited pit production capacity of PF-4 available for the first RRW, rather than having to divide it between two warhead types.<sup>98</sup>

Regarding pit reuse, Thomas D'Agostino, Acting Administrator of NNSA, said,

And what we would like to do is examine those pits [currently in storage from dismantled warheads], those small numbers of pits as potential pits that would be used in future reliable replacement warhead concepts. For example, if we were looking at providing reliable replacement concepts into a bomb, we would look primarily to one of those pits that we already know has these features. And assuming the shape is not a problem, then we would use that particular pit in that system because it would have, again, offset further expense. A warhead on top of a ballistic missile is a little bit different animal because of the constraints associated with the size. And therefore, we had to kind of start from the ground up on that particular system. And we didn't have enough of those old other pits.<sup>99</sup>

Some opponents of a new pit facility hold that PF-4's capacity could be increased beyond 50 per year. Some equipment could be removed, including that used to fabricate plutonium-238 components for powering deep space probes. Production equipment now in PF-4 was set up as a pilot project. Reconfiguring it and adding new equipment could arguably support larger-scale production, though pit production would likely have to be suspended to accommodate that effort.

**Risks of RRW vs. Risks of LEP.** Warheads put into the stockpile in the past have had unanticipated problems. RRWs could have a similar experience, just as there are recalls with cars and with laptop batteries. Significant Finding Investigations (SFIs) illustrate issues that need to be addressed. Significant Findings are defects discovered during surveillance of a warhead. If a defect is serious, an SFI is launched by the laboratory responsible for that defect to determine its cause and remedy.<sup>100</sup> A review of SFIs completed in the mid-1990s showed that significant defects were found one to two decades after the first production unit of a warhead

<sup>98</sup> Information provided by a senior Air Force official, interview with the author, September 26, 2006.

<sup>99</sup> Testimony of Thomas D'Agostino, Acting Under Secretary for Nuclear Security and Administrator, NNSA, in U.S. Congress. House. Committee on Armed Services. Subcommittee on Strategic Forces. Hearing on DOE's Atomic Energy Programs, March 20, 2007.

<sup>100</sup> See U.S. Department of Energy. Office of Inspector General. Office of Audit Services. *Audit Report: Management of the Stockpile Surveillance Program's Significant Findings Investigations*. DOE/IG-0535, December 2001, p. 1.

entered the stockpile. There are two conflicting interpretations. One is that the defects arose because of aging, such as deterioration of plastics or explosives. Another is that it may take two decades to find the final few percent of significant defects in a warhead type. That is, some flaws may be there all along, and it takes time and improved knowledge to discover them.

Congress may wish to inquire about each interpretation. Regarding RRW, why deploy it now, after the bugs have been shaken out of current warheads? Why spend large sums deploying a new warhead when it will arguably have reduced reliability with respect to SFI-type issues that may take decades to identify? Might RRW, which involves a new approach to design, introduce new risks and defects into the stockpile? Regarding current warheads, what assurance can there be that SFIs and surveillance have wrung out all the defects? Might serious defects be found in the future because they develop with age or because advances in weapons science reveal them? Congress might direct NNSA to update the 1996 SFI review to learn how warhead aging and responses have developed in the past decade.

## **Appendix A. Nuclear Weapons, Nuclear Weapons Complex, and Stockpile Stewardship Program**

This report refers to nuclear weapons design, operation, and production throughout. This Appendix describes key terms, concepts, and facilities as an aid to readers not familiar with them.

Current strategic (long-range) and most tactical nuclear weapons are of a two-stage design.<sup>101</sup> The first stage, the “primary,” is an atomic bomb similar in principle to the bomb dropped on Nagasaki. The primary provides the energy needed to trigger the second stage, or “secondary.”

The primary has at its center a “pit,” a hollow core containing fissile material (typically plutonium) and containment shells of other metals. It is surrounded by chemical explosive shaped to generate a symmetrical inward-moving (implosion) shock front. When the explosive is detonated, the implosion compresses the plutonium, increasing its density so much that it becomes supercritical and can sustain a runaway nuclear chain reaction. A neutron generator injects neutrons into the plutonium. The neutrons drive this reaction by splitting (fissioning) plutonium atoms, repeatedly doubling the number of neutrons released. But the chain reaction can last only the briefest moment before the force of the nuclear explosion drives the plutonium outward so that it becomes subcritical and can no longer support a chain reaction. To increase the fraction of plutonium that is fissioned, boosting the yield of the primary, another system injects “boost gas” — a mixture of deuterium and tritium (isotopes of hydrogen) gases — into the pit before the explosive is detonated. The intense heat and pressure of the fission chain reaction cause this gas to undergo fusion. While the fusion reaction generates energy, its purpose is to generate a great many neutrons and thus “boost” the fission chain reaction to a higher level.

A metal “radiation case” channels the energy of the primary to the secondary, which contains fission and fusion fuel. The energy ignites the secondary, which releases most of the energy of a nuclear explosion. The primary, radiation case, and secondary comprise the “nuclear explosive package.” Thousands of “nonnuclear” components are also needed to make the nuclear explosive package into a militarily usable weapon, such as an arming, firing, and fuzing system, an outer case, and electrical and physical connections linking a bomb to an airplane or a warhead to a missile.

Nuclear weapons were designed, tested, and manufactured by the nuclear weapons complex, which is composed of eight government-owned contractor-operated sites: the Los Alamos National Laboratory (NM) and Lawrence Livermore National Laboratory (CA), which design nuclear explosive packages; Sandia National Laboratories (NM and CA), which designs nonnuclear components; Y-12 Plant (TN),

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<sup>101</sup> U.S. Department of Energy, *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, DOE/EIS-0236, September 1996, summary volume, p. S-4. That page contains further information on nuclear weapon design and operation.

which produces uranium components and secondaries; Kansas City Plant (MO), which produces many of the nonnuclear components; Savannah River Site (SC), which processes tritium from stockpiled weapons to remove decay products; Pantex Plant (TX), which assembles and disassembles nuclear weapons; and the Nevada Test Site, which used to conduct nuclear tests but now conducts other weapons-related experiments that do not produce a nuclear yield. These sites are now involved in disassembly, inspection, and refurbishment of existing nuclear weapons. The National Nuclear Security Administration (NNSA), a semiautonomous part of the Department of Energy, manages the nuclear weapons complex and program.

NNSA maintains nuclear weapons and associated expertise through the Stockpile Stewardship Program (SSP), which Congress created in the FY1994 National Defense Authorization Act (P.L. 103-160, section 3138). The legislation specified that the goal of SSP is “to ensure the preservation of the core intellectual and technical competencies of the United States in nuclear weapons” through “advanced computational capabilities,” “above-ground experiments” (experiments not requiring nuclear testing), and construction of large experimental facilities. SSP has three main elements. Directed Stockpile Work involves work directly on nuclear weapons in the stockpile, such as monitoring their condition, maintaining them through refurbishment and modifications, R&D in support of specific warheads, and dismantlement. It includes the Life Extension Program and the RRW program. Campaigns provide focused scientific and engineering expertise in support of Directed Stockpile Work, in such areas as pit manufacturing and certification, computation, and study of the properties of materials. Readiness in Technical Base and Facilities funds infrastructure and operations at the nuclear weapons complex sites. While the legislation did not specify that SSP was not to involve nuclear testing, that goal seems clear from the history, and has become a goal of the program. NNSA does not rule out the possible need for testing, such as if a problem were to emerge in a warhead type that could not be remedied in any other way, but the United States has been able to maintain its nuclear stockpile without testing since 1992.

## Appendix B. Congressional Language Setting Goals

Congress has set forth many goals for the RRW program.

**[1]** That program originated as a funded activity in the conference report on the FY2005 Consolidated Appropriations Act, when conferees stated that \$9.0 million “is made available for the Reliable Replacement Warhead program to improve the reliability, longevity, and certifiability of existing weapons and their components.”<sup>102</sup> This was RRW’s Washington debut; NNSA had not requested funds for it, and the relevant congressional reports had not mentioned it.

**[2]** P.L. 109-163, the FY2006 National Defense Authorization Act, Section 3111, sets seven requirements for the program. (The text includes quotation marks because the requirements add a new Section 4204a, Reliable Replacement Warhead Program, to the Atomic Energy Defense Act, Division D of P.L. 107-314.)

- (a) Program Required. — The Secretary of Energy shall carry out a program, to be known as the Reliable Replacement Warhead program, which will have the following objectives:
  - (1) To increase the reliability, safety, and security of the United States nuclear weapons stockpile.
  - (2) To further reduce the likelihood of the resumption of underground nuclear weapons testing.
  - (3) To remain consistent with basic design parameters by including, to the maximum extent feasible and consistent with the objective specified in paragraph (2), components that are well understood or are certifiable without the need to resume underground nuclear weapons testing.
  - (4) To ensure that the nuclear weapons infrastructure can respond to unforeseen problems, to include the ability to produce replacement warheads that are safer to manufacture, more cost-effective to produce, and less costly to maintain than existing warheads.
  - (5) To achieve reductions in the future size of the nuclear weapons stockpile based on increased reliability of the reliable replacement warheads.
  - (6) To use the design, certification, and production expertise resident in the nuclear complex to develop reliable replacement components to fulfill current mission requirements of the existing stockpile.
  - (7) To serve as a complement to, and potentially a more cost-effective and reliable long-term replacement for, the current Stockpile Life Extension Programs.

**[3]** For FY2006, the House Armed Services Committee set forth many goals for RRW. Those not in the preceding text include the following:

The committee understands that by designing and replacing components and warheads in our existing arsenal, the nuclear weapons complex can take full advantage of modern design techniques, more environmentally safe materials,

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<sup>102</sup> U.S. Congress. Committee of Conference. *Making Appropriations for Foreign Operations, Export Financing, and Related Programs for the Fiscal Year Ending September 30, 2005, and for Other Purposes*, conference report to accompany H.R. 4818, 108<sup>th</sup> Cong., 2<sup>nd</sup> sess., H.Rept. 108-792, 2004, p. 951.

and efficient manufacturing processes in a way that can make our arsenal more reliable, safe, and secure. ... the committee encourages the Department of Defense and the Department of Energy to focus initial Reliable Replacement Warhead efforts on replacement warheads for Submarine Launched Ballistic Missiles. ... A second objective of this program is to further reduce the likelihood of the resumption of nuclear testing by increasing warhead design margin and manufacturability. ... [A sixth goal is] ensuring that the human capital aspect is not neglected. The nuclear complex is rapidly losing its design and production expertise, a concern highlighted by several studies in the past decade. The Reliable Replacement Warhead program will help train and sustain the weapons designers and engineers whose expertise is essential in ensuring the stockpile remains, reliable, safe and secure into the future.<sup>103</sup>

**[4]** The Senate Armed Services Committee set goals in its FY2006 report:

The committee understands from the testimony of the Administrator of the National Nuclear Security Administration (NNSA) that the goals of this program are: (1) to increase the security and reliability of the nuclear weapons stockpile; (2) to develop replacement components for nuclear warheads that can be more easily manufactured with more readily available and more environmentally benign materials; (3) to develop replacements that can be introduced into the stockpile with assured high confidence regarding their effect on warhead safety and reliability; (4) to develop these replacements on a schedule that would reduce the possibility that the United States would ever be faced with the need to conduct a nuclear test in order to diagnose or remedy a reliability problem in the current stockpile; (5) to reduce infrastructure costs needed to support the stockpile, while increasing the responsiveness of that infrastructure; and (6) to increase confidence in the stockpile to a level such that significant, additional reductions in numbers of non-deployed 'hedge' warheads can be made.

The committee supports these goals and this modest investment [\$9.4 million] in feasibility studies ... with the goal of substantially increasing the safety, security, and reliability of the nuclear weapons stockpile and with the ultimate objective of achieving the smallest stockpile consistent with our nation's security.<sup>104</sup>

**[5]** Most House Armed Services Committee Democrats presented their goals for the program in a statement of additional views in the committee's FY2006 report:

- In our opinion, the RRW program is only worth[y] of support if it:
- Truly reduces or eliminates altogether the need for nuclear testing;
  - Leads to dramatic reductions in the nuclear arsenal, including complete dismantlement of the weapons and safe disposal of fissile components;
  - Does not introduce new mission or new weapon requirements, particularly for tactical military purposes;

<sup>103</sup> U.S. Congress. House. Committee on Armed Services. *National Defense Authorization Act for Fiscal Year 2006*. H.Rept. 109-89, on H.R. 1815, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 464.

<sup>104</sup> U.S. Congress. Senate. Committee on Armed Services. *National Defense Authorization Act for Fiscal Year 2006*. S.Rept. 109-69 to accompany S. 1042, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 482.

- Reduces the reliance of the U.S. on nuclear weapons and deemphasizes the military utility of nuclear weapons;
- Significantly reduces the cost of maintaining our nuclear weapon complex, to include avoiding the need to build a modern pit facility;
- Increases nuclear security and decreases the risk of unauthorized or accidental launch and/or detonation; and
- Leads to ratification and entry into force of the Comprehensive Test Ban Treaty.<sup>105</sup>

[6] The House Appropriations Committee, in its report on FY2006 energy and water development appropriations, listed various requirements for RRW:

The Committee is supportive of the Administration taking an accelerated approach to implement a new nuclear weapons paradigm that ensures the continued moratorium on nuclear testing and results in a dramatically smaller nuclear weapons stockpile in the near future. The RRW weapon will be designed for ease of manufacturing, maintenance, dismantlement, and certification without nuclear testing, allowing the NNSA to transition the weapons complex away from a large, expensive Cold War relic into a smaller, more efficient modern complex. A more reliable replacement warhead will allow long-term savings by phasing out the multiple redundant Cold War warhead designs that require maintaining multiple obsolete production technologies to maintain the older warheads. The Committee's qualified endorsement of the RRW initiative is based on the assumption that a replacement weapon will be designed only as a re-engineered and remanufactured warhead for an existing weapon system in the stockpile. The Committee does not endorse the RRW concept as the beginning of a new production program intended to produce new warhead designs or produce new weapons for any military mission beyond the current deterrent requirements. The Committee's support of the RRW concept is contingent on the intent of the program being solely to meet the current military characteristics and requirements of the existing stockpile.<sup>106</sup>

[7] The Senate Appropriations Committee's report on FY2006 energy and water development appropriations stated:

NNSA is undertaking the RRW Program to understand if warhead design constraints imposed on Cold War systems (e.g. high yield to weight ratios that have typically driven 'tight' performance margins in nuclear design) are relaxed, could replacement components for existing stockpile weapons be more easily manufactured with more readily available and more environmentally benign materials, and whose safety and reliability could be assured with high confidence, without nuclear testing. This effort does not call into question the safety or reliability of the current stockpile but acknowledges the long-term sustainability of the legacy stockpile will be difficult. Implementation of RRW should also result in reduced life-cycle costs for supporting the stockpile.<sup>107</sup>

<sup>105</sup> U.S. Congress. House. Committee on Armed Services. *National Defense Authorization Act for Fiscal Year 2006*. H.Rept. 109-89, on H.R. 1815, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 512.

<sup>106</sup> U.S. Congress. House. Committee on Appropriations. *Energy and Water Development Appropriations Bill, 2006*. H.Rept. 109-86 to accompany H.R. 2419, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 130.

<sup>107</sup> U.S. Congress. Senate. Committee on Appropriations. *Energy and Water Appropriations* (continued...)

[8] The FY2006 energy and water conference report stated:

The conferees reiterate the direction provided in fiscal year 2005 that any weapon design work done under the RRW program must stay within the military requirements of the existing deployed stockpile and any new weapon design must stay within the design parameters validated by past nuclear tests. The conferees expect the NNSA to build on the success of science-based stockpile stewardship to improve manufacturing practices, lower costs and increase performance margins, to support the Administration's decision to significantly reduce the size of the U.S. nuclear stockpile.<sup>108</sup>

The FY2007 committee reports were released after the preliminary RRW designs were completed, and did not add requirements for RRW design.

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<sup>107</sup> (...continued)

*Bill, 2006. S.Rept. 109-84 to accompany H.R. 2419, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 155.*

<sup>108</sup> U.S. Congress. Committee of Conference. *Making Appropriations for Energy and Water Development for the Fiscal Year Ending September 30, 2006, and for Other Purposes.* H.Rept. 109-275 to accompany H.R. 2419, 109<sup>th</sup> Cong., 1<sup>st</sup> sess., 2005, p. 159.

## Appendix C. Abbreviations

AAAS	American Association for the Advancement of Science
CCRD	Competing candidate RRW design
CHE	Conventional high explosive
CPC	Consolidated Plutonium Center
DNFSB	Defense Nuclear Facilities Safety Board
DOD	Department of Defense
DOE	Department of Energy
ESD	Electrostatic discharge
ICBM	Intercontinental ballistic missile
IHE	Insensitive high explosive
LANL	Los Alamos National Laboratory
LEP	Life Extension Program
LLNL	Lawrence Livermore National Laboratory
NEP	Nuclear explosive package
NNSA	National Nuclear Security Administration
RB	Reentry Body (Navy term; same as RV)
RRW	Reliable Replacement Warhead
RV	Reentry Vehicle (Air Force term; same as RB)
SLBM	Submarine-launched ballistic missile
SSP	Stockpile Stewardship Program